Collision

VOLUME 3
ISSUE 1

The International Compendium for Crash Research

"The Trampoline Effect in Reconstruction

Comparing Different Sources of CDR Data
To "Real World" Crashes

The Accuracy of Speed Recorded by a Ford PCM
and the Effects of Brake, Yaw and Other Factors

Single Point Crush Variation

Reconstruction
Seeing Across the Years

2008 CDR User's
Conference CD
included in this issue

EXHIBIT "A"

PLUS: CABLE OPTIONS
FOR THE "CDR SYSTE
HANDYMAN"

www.CollisionPublishir

CDR CRASH DATA RETRIEVAL SYSTEM

I GOT HIT
WWW.CDR-SYSTEM.COM

New CDR Products - www.cdr-system.com

CDR System Hardware Kit

Includes all previous and new CDR cables, adaptors and modules, with the exception of the FORD PCM KIT - that part is sold separately.

NOTE: *The CDR Software subscription is also sold separately*

Chrysler Cable Kit

Includes 3 new cables.
Support for select 2004-2008 Chrysler vehicles sold in North America

FORD PCM Kit

Includes 3 new cables and a new power booster adaptor.
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Ford RCM Takata Marquette
Select 2007 Ford Vehicles

CDR OBDII DCL
cable withVPS

New CDR Power Supply
w/detachable cord

Bosch is planning two CDR product releases this year which will include late model GM, Ford and Chrysler vehicle coverage, new cables for direct data retrieval and enhancements to existing Chrysler and GM vehicle support.

www.cdr-system.com | (800) 280-7940

I Got Hit LLC is the exclusive distributor for Bosch Crash Data Retrieval products.

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Evidence Recorder 4 is the latest version of the world's best-selling evidence collection software built specifically for professional reconstructionists.

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When accuracy and precision are non-negotiable – fortunately, there is MapScenes.

A good partner brings a lot of attributes to the table. Consider just a few of the features and functions built into Evidence Recorder:

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- Optional raw file encryption ensures only authorized products and users can access your raw file
- Advanced offset routines for use with prismless total stations
- Easy linework tools help you draw your scene while you collect evidence
- Automatic modes for trilateration and baseline offsets included for LTI lasers
- Easily sync your Evidence Recorder with your MapScenes desktop program

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YOU KNOW WHAT'S AT STAKE. BUT, WHAT HAVE YOU GOT TO GAIN?

WE THINK, QUITE A BIT!

MapScenes®
S Y S T E M S

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On the Cover: *Crash scenes like this one leave tangible evidence for the reconstructionists but there are intangibles, too. The cover photo is from a crash test we can use to evaluate one of those intangibles.*
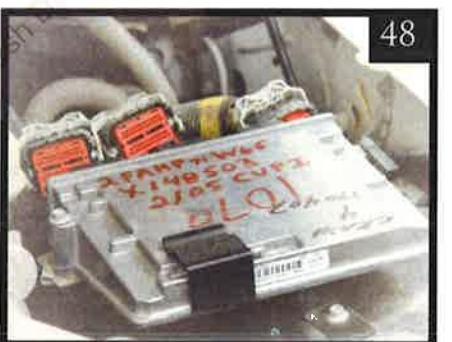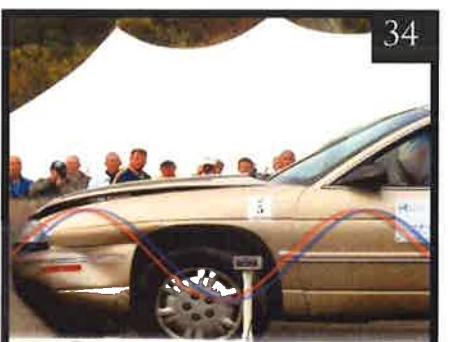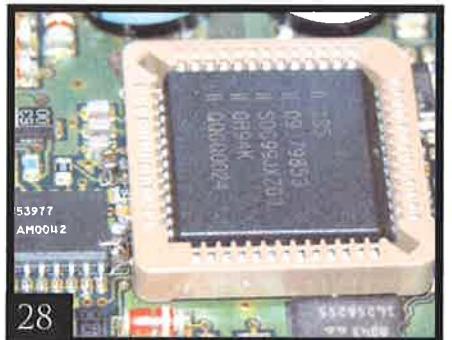
from the editor

This issue marks the beginning of the third year of Collision Magazine. Over the past two years we have set a standard for publishing current crash research. Gone are the days of reporting what's otherwise publicly available on the web or in news releases, Collision began with specific conference proceedings and has emerged to include new and original articles and technical papers all relating to crash research.

In this issue we've included an index of all articles that have been published in Collision: The International Compendium of Crash Research, which include a wide variety of topics. Those articles include busses, snow mobiles, crush, momentum applications, motorcycles, and more. But there's another aspect of all this I think people overlook: the enclosed disk. Collision is more than a paper-and-ink magazine, every issue also includes either a CD or data DVD with everything from conference presentations to gigabytes of photos to video of crash tests. No other publication nor resource offers that kind of content on top of the articles and material in the actual magazine itself.

The material in this issue runs the gamut of a personal account of how a training day was set up to examine how well airbag control modules hold up in a fire and whether or not they can still be downloaded after exposure to a fire to detailed and interesting accounts of how to make our own cables for airbag control modules, how to move chips from one airbag control module to another and a detailed analysis of single point crush variations.

The trained observer may have noticed that a good bit of those topics in this issue relate to airbag control modules in one form or another and crash data. Yes, it's true, this issue - like the very first one as well as the first one last year - relate to the CDR User's Conference. For that reason, the content is "CDR-heavy." The reason? Because Collision was originally created to publish the proceedings of the 2006 CDR User's Conference after that material was rejected by another publication and so, Collision was born.

But have we been limited to CDR topics? Of course not. Writing this, it wasn't my intent to trumpet the strengths of Collision, but rather I thought it important to point out to the small, but periodically loud, minority of people who don't seem to "understand Collision:" that one issue of Collision is based on the CDR User's Conference and the other is based on the ARC-CSI Crash Conference (held every year in Las Vegas) and it's more than "a magazine" not to mention a lot more than a collection of web articles and news clippings.

Another reason I bring this up is to put out a call for submissions for the 2009 CDR User's Conference. We already have some interesting topics and presenters lined up but there's room for more. The CDR User's Conference is THE premier crash data conference and the presenters from this past conference (as seen on the enclosed conference proceedings disk) include representatives from the manufacturers and industry and gave end user's an opportunity to get some hands-on time with the latest release of the Bosch CDR System.

While we're talking about what's coming up in Crash Data Retrieval, Bosch recently announced that their planned updates to the CDR System this year (2008) include expanded Chrysler coverage going into model year 2009 vehicles, GM vehicles for model year 2009 and model year 2009 Ford vehicles. Additional Ford coverage should include models not presently accessible including the Edge. You can find out more about coverage and other current issues with CDR by subscribing to the free quarterly CDR newsletter at http://cdr-system.com/cdr-newsletter/index.html.

There's a lot of information out there, a lot of it free and as we all know, information is power. So, take advantage of this additional resource.

The next issue of Collision will be devoted to the proceedings of the 2008 ARC-CSI Crash Conference in Vegas. It promises to be one of the most widely attended conferences of the year and that next issue should include data from more than 6 crash tests.

In the meantime, next year's CDR User's Conference (January 26-28, 2009) is actively in the planning phase. If you want to participate as a speaker go to http://crashconferences.com/cdrconference/2009cdrconference.html to submit your proposed presentation. Beyond that, if you have thought about writing something for the next issue of Collision, please don't hesitate to email it to us!

Managing Editor

Collision
PUBLISHING

Collision Staff

Scott Baker   Owner, Managing Editor
Sean Haight   Editor
Tonya Baker   Advertising Manager
Michelle Jennings   Customer Relations

Conference CD

Included with this issue of Collision is the 2008 Crash Data Retrieval User's Conference CD. This CD includes all the Power Point presentations from the conference and any additional data supplied.

Submit an Article

If you would like to submit an article to be published in Collision please email us your article for review or call us toll free 800-280-7940. Email: editor@collisionpublishing.com

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From the Desk of the President

John H. Meserve
NAPARS1@comcast.net

Greetings from Las Vegas, where the 7th annual ARC-CSI Crash Conference, co-sponsored by NAPARS, has just concluded. As has been the case each year, the 2008 edition of this mega crash conference was bigger and better than ever and had a very international flavor as well, with attendees from Australia, France, Japan, Jamaica, Puerto Rico, Mexico, New Zealand and Canada. Some of those international attendees were already NAPARS members but we welcomed two new members from Japan and two from Jamaica, as well as many others from the United States, at the conference. Congratulations to Roman Beck of El Cadon, California, an attendee at this year's conference who won a free registration to the 2009 ARC-CSI Crash Conference in a drawing which was open only to NAPARS members. Stay alert as there will be other opportunities to win free registrations to conferences and merchandise during what has proved to be a very busy 2008 and as we head toward our 25th anniversary in 2009!

On the near horizon is the Southeastern Conference in Atlanta July 21-24, of which NAPARS is a principal co-sponsor, and not far behind is the Joint Annual Conference for NAPARS-NATARI-MdTAI-NJAARS-NYSTARS, which will hosted by the New Jersey association in Atlantic City, New Jersey October 15-17. Our annual meeting, which includes election of officers and directors, will be in Atlantic City. Be sure to mark those events on your calendar.

As I indicated in my last Collision message, NAPARS will be celebrating its 25th birthday during 2009 and we continue looking for topic ideas and possible locations for that special occasion. Time is running out on the decision-making process as the implementation process needs to begin very soon. So please let me and/or any member of the Board of Directors know your thoughts and suggestions as soon as possible.

NAPARS has been and will continue to be a leader in the rapidly-evolving reconstruction field. A reminder to all our members (and potential members too): my "door" is always open. We will be implementing new electronic tools in the very near future to better enable us to more efficiently communicate with all of our members and potential members. Please feel free to contact me at anytime with comments, questions, suggestions or complaints; the more we all work together the stronger our organization will be in the days and years ahead. Hope to see you at a future NAPARS-sponsored event!

And members: wear your affiliation with NAPARS proudly. New logo shirts, hats and other merchandise are now making their appearance in the NAPARS store on the website, so be sure to check it out, and we will have many new apparel items at both the Atlanta and Atlantic City conferences as well.

The International Association of Accident Reconstruction Specialists is one of the oldest associations dedicated to expanding the knowledge and training of accident reconstructionists. Formed in 1980, we have members from several different countries as well as many different states across the U.S. We have three levels of membership. Our highest level, Fellow, includes a peer review of a reconstruction project. This peer review feature can be very beneficial to a member seeking expert witness qualification in court. One of the criteria a judge can consider when deciding if a person qualifies as an expert is a peer review of his or her work. We offer opportunities for a member to publish work or research in the field of accident reconstruction. This, also, can be very important when qualifying as an expert witness in court proceedings.

Membership in IAARS has other advantages, including a discount (from IAARS) on a subscription to Collision Magazine, member discounts at our training seminars and others listed on our web page, www.iaars.org.

We have annual training opportunities at different locations across the country. We try to have some sort of actual vehicle testing at each seminar, including full scale vehicle crashes. As a member, you would have access to a vast archive of results from many different and sometimes quite unique tests. We are offering two training opportunities for 2008. One location is planned for an 8-day cruise from Vancouver, British Columbia to Alaska and back. The other location is planned for Atlanta, GA in conjunction with the SCARS annual seminar. More information can be found on our web site, www.iaars.org.

If you have any questions about IAARS or the application process, please feel free to contact me or any of the board members listed on our web page.

Sincerely,
Dan Lofgren
President, IAARS

ASPACI Inc.

ASPACI is a non-profit society whose members have joined to share in the challenge of analysing the complicated issues of road collision investigation.

ASPACI was formed in 1991 by a group of police and collision reconstructionists who felt there was a need for information sharing between police and associated institutions in the Australia, South East Asia, New Zealand and South Pacific area. Its primary function is to assist in the spreading of knowledge and enhancing expertise in the science. The Association seeks to promote a professional approach to collision investigation and to encourage the highest standard of ethics, integrity and honesty among its members.

The early days saw the number of members vary with the base of the association in Victoria, Australia. ASPACI became ASPACI Incorporated in 1993 in Victoria. Now we boast members from all over mainland Australia, New Zealand., United Kingdom, and the United States, as well as parts of Asia.

Membership to ASPACI is open to all persons engaged in collision investigation and its allied fields. The association members include Engineers, Police Officers, Independent Consultants, Scientists, Insurance Corporations, Manufacturers and Safety personnel. ASPACI is not a Trade Association or Political Lobby group, nor is it a Police organisation.

My name is Kent Boots, and I am the Chairperson on the California Association of Accident Reconstruction Specialists (CA2RS) board of directors. I'd like to start by telling you a little about our organization. CA2RS was formed in April of 1998 with the objective of providing education, training, and resources in the field of accident reconstruction. At the end of our first year we had just over 100 members, and we have grown to over 300 members. Current membership dues are $50 to join the organization and $40 a year to renew your membership.

As part of your paid membership you are allowed to attend all of the quarterly trainings for free. We have three quarterly training sessions a year for both Northern and Southern California, a total of six training sessions. The Northern California training sessions are the first month of each quarter; January, April, and July. The Southern California training sessions are the second month of each quarter; February, May, and August. We do our best to offer the same training for both the northern and southern training sessions.

In lieu of a 4th quarter training session we have a two-and-a-half-day, conference starting on Thursday and ending on Saturday at noon. There is a fee to attend the conference which typically includes breakfasts and lunches as well as a vendor reception. The conference topics have been "themed" such as Commercial Vehicle Collision Investigation, Bicycle and Other Inline Wheeled Vehicle Collisions, Motorcycle Collisions, and Emergency Vehicle Collision Investigation. We have also had multi-topic conferences such as this year; more conference information is available on the "Events" portion of our web site.

For more information about our organization, training, or conference, please visit our web site at www.ca2rs.com. If you have any questions, please don't hesitate to contact me via e-mail at chairperson@ca2rs.com.

Kent E. Boots

CALENDAR CONFERENCES, TRAINING, AND MEETINGS

JULY 2008

7/14/2008 - 7/16/2008
Sacramento (McClellan), CA
Diagramming with CrashZone/CrimeZone - Basic

7/17/2008 - 7/18/2008
Sacramento (McClellan), CA
Diagramming with CrashZone/CrimeZone - Advanced

7/20/2008 - 7/24/2008
Atlanta, GA
2008 Annual South Eastern Crash Conference
IAARS - NAPARS - SeARS - SCARS

AUGUST 2008

8/4/2008 – 8/8/2008
North Las Vegas, NV
Pedestrian/Bicycle Involved Collisions
Collision Safety Institute
(www.collisionsafety.net)

8/11/2008 - 8/13/2008
Sacramento (McClellan), CA
ACTAR Test Preparation Course

8/18/2008 – 8/22/2008
Elk Grove, IL
CDR Certification Course
Collision Safety Institute
(www.collisionsafety.net)

8/18/2008 - 8/29/2008
Fort Pierce, FL
Advanced Traffic Crash Investigation
IPTM

SEPTEMBER 2008

9/8/2008
Vallejo, CA
Crash Data Retrieval Technician Course
707-649-3407

9/10/2008 - 9/12/2008
Bloomington, IL
22nd Annual IATAI Crash Conference
Illinois Association of Technical Accident Investigators

9/15/2008 – 9/19/2008
Poway, CA
CDR Certification Course
Collision Safety Institute
(www.collisionsafety.net)

9/15/2008 - 9/26/2008
Orlando, FL and Tampa, FL
Advanced Traffic Crash Investigation
IPTM

9/15/2008 - 9/19/2008
Jacksonville, FL
Pedestrian/Bicycle Crash Investigation
IPTM

9/22/2008 - 10/4/2008
Jacksonville, FL
Advanced Traffic Crash Investigation
IPTM

9/22/2008 – 9/26/2008
Burien, WA
CDR Certification Course
Collision Safety Institute
(www.collisionsafety.net)

OCTOBER 2008

10/6/2008 - 10/17/2008
Gresham, OR
Advanced Traffic Crash Investigation
IPTM

10/15/2008 - 10/17/2008
Atlantic City, NJ
Annual Combined Crash Conference
Hosted by NJARR

10/20/2008 – 10/24/2008
Fort Worth, TX
CDR Certification Course
Collision Safety Institute

10/20/2008 - 10/24/2008
Tempe, AZ
Pedestrian/Bicycle Crash Investigation
IPTM

10/20/2008 - 10/31/2008
Evanston, IL
Traffic Accident Reconstruction 1
Northwestern Center for Public Safety

10/20/2008 - 10/31/2008
St. Petersburg, FL
Advanced Traffic Crash Investigation
IPTM

NOVEMBER 2008

11/3/2008 - 11/7/2008
Evanston, IL
Traffic Accident Reconstruction 2
Northwestern Center for Public Safety

11/3/2008 - 11/7/2008
Jacksonville, FL
Advanced Commercial Vehicle Crash Investigation
IPTM

11/3/2008 - 11/7/2008
Tempe, AZ
Human Factors in Traffic Crash Reconstruction
IPTM

DECEMBER 2008

12/9/2008 – 12/12/2008
Golden, CO
CDR Certification Course
(Technician and Analyst)
Collision Safety Institute
(www.collisionsafety.net)

JANUARY 2009

1/12/2009 - 1/16/2009
Sacramento (McClellan), CA
Human Factors for Traffic Accident Reconstruction
866-866-7100

1/19/2009 - 10/30/2009
Evanston, IL
Traffic Accident Reconstruction 1
Northwestern Center for Public Safety

1/26/2009 – 1/28/2009
Houston, TX
2009 CDR Users Conference
www.CrashConferences.com

FEBRUARY 2009

2/2/2009 - 2/6/2009
Evanston, IL
Traffic Accident Reconstruction 2
Northwestern Center for Public Safety

MARCH 2009

3/2/2009 - 3/13/2009
Evanston, IL
Accident Investigation 1
Northwestern Center for Public Safety

3/16/2009 - 3/27/2009
Evanston, IL
Accident Investigation 2
Northwestern Center for Public Safety

If you would like to list an event, class, conference or seminar in a future issue of Collision, please send us an email with complete details of the event.

Email:
editor@collisionpublishing.com

Phone: 800-280-7940

PROFESSIONAL SOCIETIES

ARC Network - www.accidentreconstruction.com - Founded in 1998, the ARC Network is the largest Internet portal web site for the industry of accident reconstruction and traffic accident investigation. This organization provides resources and information for all areas of accident reconstruction and traffic accident investigation including research, news, expert discussion, events, products and services, expert witness directory, book store, education services directory, police department directory and a member's only section that provide valuable online databases and tools to assist in daily accident reconstruction requirements.

ASPACI - www.aspaci.org.au - ASPACI is a non-profit society whose members have joined to share in the challenge of analysing the complicated issues of road collision investigation. ASPACI was formed in 1991 by a group of police and collision reconstructionists who felt there was a need for information sharing between police and associated institutions in the Australia, South East Asia, New Zealand and South Pacific area. Its primary function is to assist in the spreading of knowledge and enhancing expertise in the science. The Association seeks to promote a professional approach to collision investigation and to encourage the highest standard of ethics, integrity and honesty among its members.

CA2RS - www.ca2rs.com - CA2RS was created to provide accident reconstruction training and resources to its members. There is a growng need for more local resources in the accident reconstruction field. This organization has grown to over 260 paid members and are always looking for ways to strengthen and increase their membership.

CATAIR - www.catair.net - The Canadian Association of Technical Accident Investigators and Reconstructionists (CATAIR) was founded in 1984 to meet the growing demand for a professional organization that subscribed to a code of professional conduct. CATAIR membership is open to individuals involved in all aspects of road safety. Current membership is in excess of 250. presently, our membership is comprised of active and retired police officers, professional engineers, automotive engineers, engineering technologists, private consultants and representatives from the insurance industry.

FARO - www.faro-inc.org - FARO, officially known as Forensic Accident Reconstructionists of Oregon, was chartered in June 1994 under the laws of the State of Oregon. Officially designated as a non-profit, mutual benefit corporation, FARO exists as a voluntary professional association of individuals who practice forensic reconstruction in Oregon.

IAARS - www.iaars.org - The International Association of Accident Reconstruction Specialists was started in 1980 as a training and networking resource for members. It is believed we are the oldest such crash reconstruction organization. Our membership consists of Law Enforcement as well as Engineers and PhD's. We have members from 38 states as well as Canada, England, Singapore, Spain and West Australia. Our association is a little different from many others in that we have a peer review process for membership. This peer review is a specific area of judicial consideration when admitting an expert opinion in court. The annual seminars, held in different locations nationwide, not only provide instruction on specific topics by experts in the field, they provide face-to-face discussions on how other people approach reconstructing a crash. The old saying "two heads are better than one" is definitely true in accident reconstruction. The next seminar will be the Big Event in Houston, TX in September 2006.

IATAI - www.iatai.org - The Illinois Association of Technical Accident Investigators was born after several members of the Illinois State Police completed their training in traffic crash reconstruction. They saw the need for a way to share information, experiences and grow as Accident Investigators. These founding members set four goals for the organization; 1. To provide professional standards for members investigating accidents; 2. To promote the continued expansion of members knowledge in the area of technical accident investigation.; 3. To promote Traffic Safety through accident investigations; and 4. To promote improved capability of each agency through training and idea exchange. Since 1986, IATAI has held annual training conferences throughout the State of Illinois. These conferences serve to bring valuable training from across the country into Illinois. Our membership reaches out to 26 states in both the public and private sector.

MATAI - www.mdatai.org - MATAI continues to be innovative and willing to meet the needs of its membership. Over the years, MATAI has grown into a internationally renowned organization. MATAI has sponsored or co-sponsored numerous conferences that have been attended by fellow investigators from around the world. These conferences have included relevant and at times, spectacular test collisions involving cars, trucks, motorcycles, pedestrians, bicycles, and even a Metrobus.

MATAI - www.matai.org - Founded in 1988, the Midwest Association of Technical Accident Investigators (MATAI) was formed to provide a professional affiliation for individuals who have a primary interest in the technical aspects of motor vehicle traffic collisions. The Association is dedicated to the exchange of information and ideas to improve investigative techniques and procedures In addition, MATAI provides a communication source between other individuals and affiliations involved in this vital area of public safety. MATAI's primary objective is to meet the needs of the people directly involved in the initial investigative process.

NAPARS - www.napars.org - The National Association of Professional Accident Reconstruction Specialists is a non-profit organization whose members have joined together to share the challenge of dealing with the complex problems of accident reconstruction and to upgrade and ultimately professionalize the accident reconstruction field. NAPARS is open to all persons who are interested in the fields of traffic accident reconstruction and highway transportation safety. Present membership exceeds 1,100 and includes police officers, engineers, consultants and government safety personnel. NAPARS is also the Premier Industry Partner for Collision Magazine.

NATARI - www.natari.org - The National Association of Traffic Accident Reconstructionists and Investigators (NATARI) was established as a non-profit Pennsylvania corporation in 1984. The goal of NATARI is to provide a source of information to be shared among accident professionals on a national basis. This goal is reflected in the NATARI logo comprised of an outline of the nation, a broken wheel signifying a traffic collision and the words "to solve for safety".

NJAAR - www.njaar.org - The New Jersey Association of Accident Reconstructionists started in 1991 as a dream of a few New Jersey police officers who wanted to create a network of individuals with interests in the field of accident reconstruction. Its membership has grown to encompass individuals from many states in all fields of accident reconstruction. We have a large membership base that includes many professionals not only from the police community, but the private sector as well.

NYSTARS - www.accidentreconstruction.com/nystars - The mission of NYSTARS is to organize into one body, professionals in the field of ground vehicle collision reconstruction and related activities, who support and maintain a high standard of ethics, integrity, credibility and honor in the field of collision reconstruction; to encourage training programs relating to motor vehicle collision investigation and reconstruction through research and communication of matters of mutual interest; to promote traffic safety and foster a spirit of brotherhood among the organization's members.

SATAI - www.satai.com - Established as a non-profit corporation in 1982, the Southwestern Association of Technical Accident Investigators, Inc. goal is to encourage and promulgate the development of professional technical accident investigation and highway safety; promote research and development of programs leading to better technical accident investigations; and to promote the development and dissemination of new knowledge in the fields of traffic safety, accident investigation and reconstruction. The Association is organized and operated for scientific and educational purposes.

SOAR - www.accidentreconstruction.com/soar - An organization of accident reconstructionists dedicated to increasing knowledge, enhancing auto engineering, improving traffic safety and the free exchange of information. Membership is open to all people in all aspects of traffic transportation. Membership is comprised of active and retired police officers, professional engineers, automotive engineers and private consultants. We have members throughout the world.

TAARS - www.accidentreconstruction.com/taars - TAARS was organized in 1986 as an organization dedicated to advancing Research, Knowledge, Education and Safety in the field of accident reconstruction. TAARS is a broad based organization with members from many different fields, including law enforcement, private investigators, engineers and attorneys. TAARS has a current membership of over 220 members.

WATAI - www.accidentreconstruction.com/watai - WATAI was formed in 1979 and is the oldest of the technical accident investigation organizations in the United States. Twenty-five plus years since its inception WATAI remains true to its original mission; "to promote education and research in the field of accident investigation; to encourage interdisciplinary communication between the practitioners of accident investigation; and to cooperate and participate with other organizations dedicated to the science of accident investigations". To that end WATAI sponsors semi-annual conferences. The Spring Conference usually takes place in May and the Fall Conference generally in the onth of October.

"Electronic Stability Program, Drifting and Utilising Forensic Science Applications at Crash Scenes"

ASPACI 2008
5 – 8 October 2008
Sebel Hotel, Albert Park,
65 Queens Road, Melbourne
T +61 3 9529 4300

The theme of the 2008 conference is electronic stability program, drifting and utilising forensic science applications at crash scenes. Expert speakers from Bosch, Vic Roads, Victoria Police, the Transport Accident Commission as well as the Victoria State Coroner will provide an insight to the benefits of electronic stability programs in saving peoples life's on our road network as well as a technical insight into the different versions of electronic stability control available. A number of dynamic vehicle tests will be conducted on Tuesday the 7th of October, 2008 at the Anglesea Proving Ground that will involve critical speed, oversteer and understeer vehicle manoeuvres with and without ESP to see whether critical speed formulae based on physics circular motion can be applied to cars fitted with ESP.

The Safe Cars Save Lives, Vehicle Safety Roadshow, ESP simulator will be present at the conference so delegates can experience the effects in a car with and without ESP.

Program Overview:

The Welcome Reception and pre-registration will be in the afternoon of Sunday 5th October.   The Conference will be opened on Monday 6th October by the Victoria State Coroner, Graeme Johnstone who will discuss initiatives to drive down the Road Toll, followed by Carl Liersch from Bosch Australia who will discuss ESP systems function, software versions, operation, calibration, vehicle testing, case studies and download of information from vehicles fitted with ESP.   The ASPACI Biannual General Meeting will be held Monday immediately after the completion of paper presentations.
Tuesday 7th of October will be the test day at Anglesea and will involve critical speed, oversteer and understeer vehicle manoeuvres with and without ESP to see whether critical speed formulae based on physics circular motion can be applied to cars fitted with ESP. Transport to and from venue will be by Victoria Police Coaches.   Catered lunch will be provided.

The Conference Dinner will be Tuesday evening where a guest speaker will enlighten the delegates.

Wednesday 8th of October there will be presentations from Adam Woltanski of Knorr-Bremse who will talk about ESP applications in heavy vehicles and will be followed by Barry Hendry / Chris Jones from Vic Roads who will discuss investigations, experiences, policy and information regarding electronic stability control systems in cars and trucks.   Results of field testing will be provided.

Social Program:
Please indicate your attendance by ticking the appropriate boxes on the Registration Form.

Welcome Reception:
The Conference Welcome Reception will be held from 5.00 p.m. to 7.00 p.m. on Sunday the 5th October in the Washington Room at the Sebel, Albert Park.   The cost for this is included in the full registration fee. Additional tickets may be purchased at $45 each on the registration form.

Conference Dinner:
The Conference Dinner will be held from 7.00 p.m. for pre-dinner drinks on Tuesday 7th October in the Washington Room at Sebel, Albert Park. Join colleagues for a relaxing 3 course dinner with beverages. The cost of the dinner is included in the full registration fee. Additional tickets may be purchased at $90 each on the registration form.

Confirmed Speakers:
- Assistant Commissioner Ken Lay - Traffic & Transit Safety, Victoria Police. Arrive Alive II, Victoria's Road Safety Strategy.
- Graeme Johnstone - Former Victoria State Coroner. Driving Down the Road Toll by Design.
- Chris Woods - Bosch Australia. Operation, Testing & Case Studies of Electronic Stability Control in Australia.
- Mike Greenfield - Visual Statement. Applications for Crash Investigation and Reconstruction.
- Chris Jones - Vic Roads Vehicle Safety Standards. Safer Vehicles for ictoria's Roads.

- Senior Sergeant Michael Talbot, Senior Constable Glen Urquhart. MCIG Case Studies involving ESP.
- Adam Woltanski - Knorr–Bremse. ESP and other modern electronic safety features in Heavy Vehicles.
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The registration fees for the conference are inclusive of GST.

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Full Registration – Non member	$780	Full Registration – Non member	$850
Day Registration	$280	Day Registration	$320
Field Day	$320	Field Day	$380

Full Registration includes Welcome Reception, conference dinner, attendance at all sessions, morning and afternoon teas and lunches during the conference, delegate pack and handbook.

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Quantifying the Aerodynamic Forces Acting on Objects During a Fall

-Kevin Adkins

$$D = \frac{1}{2} \rho v^2 S C_D$$

The kinematic equations of motion are for use during uniformly accelerated motion. Consequently, the use of these equations necessitates the exclusion of aerodynamic forces (air resistance) from consideration since this force varies with the square of the object's speed. In this article, the aerodynamic forces which act on a vehicle and human are analyzed in the context of a fall calculation in order to determine this force's affect on launch velocity calculations.

For large bodies moving at ordinary speeds, such as a car moving through the air, the flow of air past the body creates an aerodynamic drag force. This net drag force results from a combination of skin friction and pressure drag. Skin friction drag is caused by the actual contact of the air particles against the surface of the vehicle. Because skin friction drag is an interaction between a solid (the vehicle surface) and a gas (the atmosphere), the magnitude of skin friction drag depends on the properties of both the solid and the gas.

While skin friction drag is a function of the roughness of the vehicle's surface and the length that the air is in contact with the vehicle, pressure drag is dependent on the vehicle's shape. Pressure drag results from the flow of air around the vehicle. Air flow around the vehicle attempts to 'hug' the vehicle's surface; but, abrupt changes in the vehicle's geometry result in the air suddenly breaking free of the surface contour and creating chaotic (turbulent) flow. This separated flow creates pockets of low and high pressure, thus the name pressure drag. A difference in air pressure, lower pressure in the separated flow behind the vehicle, literally sucks the vehicle backward.

The equation used to calculate drag is:

$$D = \frac{1}{2}\rho v^2 S C_D$$

Considering each of the parameters,

- ρ represents the density of the air. It increases when the density of the medium that the vehicle is passing through increases. A standard atmosphere, sea level value of 0.00237 slug per cubic foot, (1.229) kg per cubic meter is used.
- v is the speed of the vehicle. Its squaring results in the drag force increasing four times when the speed doubles.
- S is the frontal area of the vehicle. This can be visualized as the area of the vehicle projected onto a plane which is perpendicular to its motion.
- C_D, the drag coefficient, characterizes the aerodynamic design of the vehicle. The dimensionless drag coefficient falls within the range of 0.30 to 0.36 for most passenger vehicles, ranges between 0.35 to 0.45 for sport utility vehicles (SUVs), and can drop to 0.25 for sport cars.

The grouping $\frac{1}{2}\rho v^2$ may be recognized as the expression for dynamic pressure. Identifying this allows the drag equation to be understood as the amount of dynamic pressure, over the reference area S, that gets converted into a drag force through the coefficient of drag, C_D. The coefficient of drag, determined experimentally through wind tunnel testing, allows all of the aerodynamic effects, simple and complex, to be conveniently captured. The overall equation itself can be derived through conservation of energy or conservation of momentum arguments.

To investigate the effect that air resistance has on an object, it is necessary to depart from the premise that the horizontal velocity imparted to a projectile at launch remains constant throughout its trajectory. Inclusion of air resistance introduces a variable acceleration in the direction directly opposite to the projectile's velocity. Hence, air resistance works in conjunction with the vertical acceleration due to gravity and it changes the otherwise uniform horizontal component of motion to a decelerated motion. This change in acceleration results in a reduced maximum height and also a decreased distance traveled for an object.

Introducing the force of air resistance into the equations of motion for a projectile is not difficult. However, calculating the constantly changing components of acceleration as the drag force changes with velocity as a function of time is a bit more complex. However, this complexity can easily be handled by a numerical method set-up in a spreadsheet. Remembering the acceleration values for a projectile in the absence of air resistance are:

$$a_x = 0 \qquad\qquad a_y = -g$$

We must add to these components the acceleration resulting from the drag force. Remembering the equation for drag put forth above was

$$D = \frac{1}{2}\rho v^2 S C_D$$

$$v = \sqrt{v_x^2 + v_y^2}$$
where

and using Newton's 2nd Law, where the drag force is substituted in for the force

$$\vec{F}_{net} = m\vec{a}$$

the components of acceleration, taking into account the air drag force, become

Horizontal Acceleration   Vertical Acceleration

$$a_x = -\frac{1}{2m}\rho v v_x S C_D \qquad a_y = -g - \frac{1}{2m}\rho v v_y S C_D$$

When each of these expressions is considered, we see that each is a function of velocity. Velocity, being a function of time, introduces the calculation complexity mentioned above. One way to deal

with this complexity is to look at the acceleration components over discrete time intervals where the acceleration can be treated as relatively constant for short time periods. This will allow the use of the kinematic equations for projectile motion. Specifying the position and velocity at some time t, we can subsequently calculate the position and velocity of the projectile at a slightly later time, $t + \Delta t$, and continue to do so throughout the projectile's trajectory. While it would be tedious to calculate by hand these values at numerous small time steps throughout the projectile's trajectory, this doesn't pose any challenge for a computer. Therefore, using the expressions for a_x and a_y put forth above we utilize the following kinematic equations:

Horizontal component	Vertical component
Velocity: $v_x + \Delta v_x = v_{x_o} + a_x\Delta t$	$v_y + \Delta v_y = v_{y_o} + a_y\Delta t$
Distance: $x + \Delta x = x_0 + v_{x_o}\Delta t + \frac{1}{2}a_x(\Delta t)^2$	$y + \Delta y = y_0 + v_{y_o}\Delta t + \frac{1}{2}a_y(\Delta t)^2$

Utilizing the expressions above in a spreadsheet, with appropriate constants and initial values, and the newly developed acceleration expressions, the trajectory of an object can be calculated that include aerodynamic affects.

Consider a Ford Focus that travels through the air after being launched at a 30 degree angle, at a speed of 45mph (20.1 m/s), and lands at the same height. The input values for this scenario follow as [1]:

$C_D = 0.36$	m = 80.6slugs (1176kg)	$v_0 = 45mph(20.1m/s)$
$\theta = 30°$	$S = 26.33ft^2(2.4m^2)$	$\Delta t = .01s$

The numerical method put forth above produces a travel distance of 116.3ft (35.4m). Plugging the above values into the kinematic equations for constant acceleration which ignore air resistance, a distance of 117.3 ft (35.7m) is calculated. Hence the two methodologies calculate a travel distance difference of 1.0ft.

Considering values consistent with a human that becomes

$C_D = 1.2$	m = 5.0 slugs (73kg)	$v_0 = 45mph(20.1m/s)$
$\theta = 30°$	$S = 12ft^2(1.1m^2)$	$\Delta t = .01s$

where wind tunnel tests give a range of values for an upright human of 1.0-1.3 and for a downhill skier of 1.0-1.1 [2].

The numerical method put forth above, which accounts for air resistance, produces a travel distance of 112.3ft (34.2m). Plugging the above values into the kinematic equations for constant acceleration, which consequently ignore air resistance, a distance of 117.3 ft (35.7m) is again calculated. Hence the two methodologies calculate a travel distance difference of 5.0ft.

Inserting each of these distances into the fall velocity equation, with the same applicable inputs as above, produces initial velocities of:

Fall Velocity

$$v = d\sqrt{\frac{g}{2\cos\theta(d\sin\theta - h\cos\theta)}}$$

where

- v is initial velocity
- d is the horizontal distance traveled
- g is the acceleration due to gravity
- h is the vertical distance traveled from takeoff to landing
- θ is the angle at takeoff measured from the horizontal

Distance Traveled [ft] (calculated above)	Initial Velocity [ft/sec] (Fall Equation)
116.3	65.8
117.3	66.0
112.3	64.6

Table 1. Initial velocities calculated by the fall equation using distances calculated above.

Conclusion

In the scenario put forth involving a vehicle, the exclusion of air resistance resulted in a .9% increase in the vehicle's distance traveled. Consequently, this resulted in a .3% increase in the vehicle's calculated initial speed. Similarly, for the scenario involving a human, the exclusion of air resistance resulted in a 4.5% increase in the human's distance traveled. Consequently, this resulted in a 2.2% increase in the individual's calculated initial speed. These differences in initial speeds are inconsequential in the context of a reconstruction. However, the review of this exercise should allow the reader to be able to quantify the affect of air resistance in analogous scenarios before dismissing it.

Sources:

1. caranddriver.com. Hachette Filipacchi Media U.S. Inc. http://www.caranddriver.com.

2. Advanced Topics in Aerodynamics. A. Filippone. 2004. http://aerodyn.org/Drag/tables.html.

C

Vehicle Fires and Airbag Modules

Deputy Timothy Erhardt
Kent County Sheriff Department
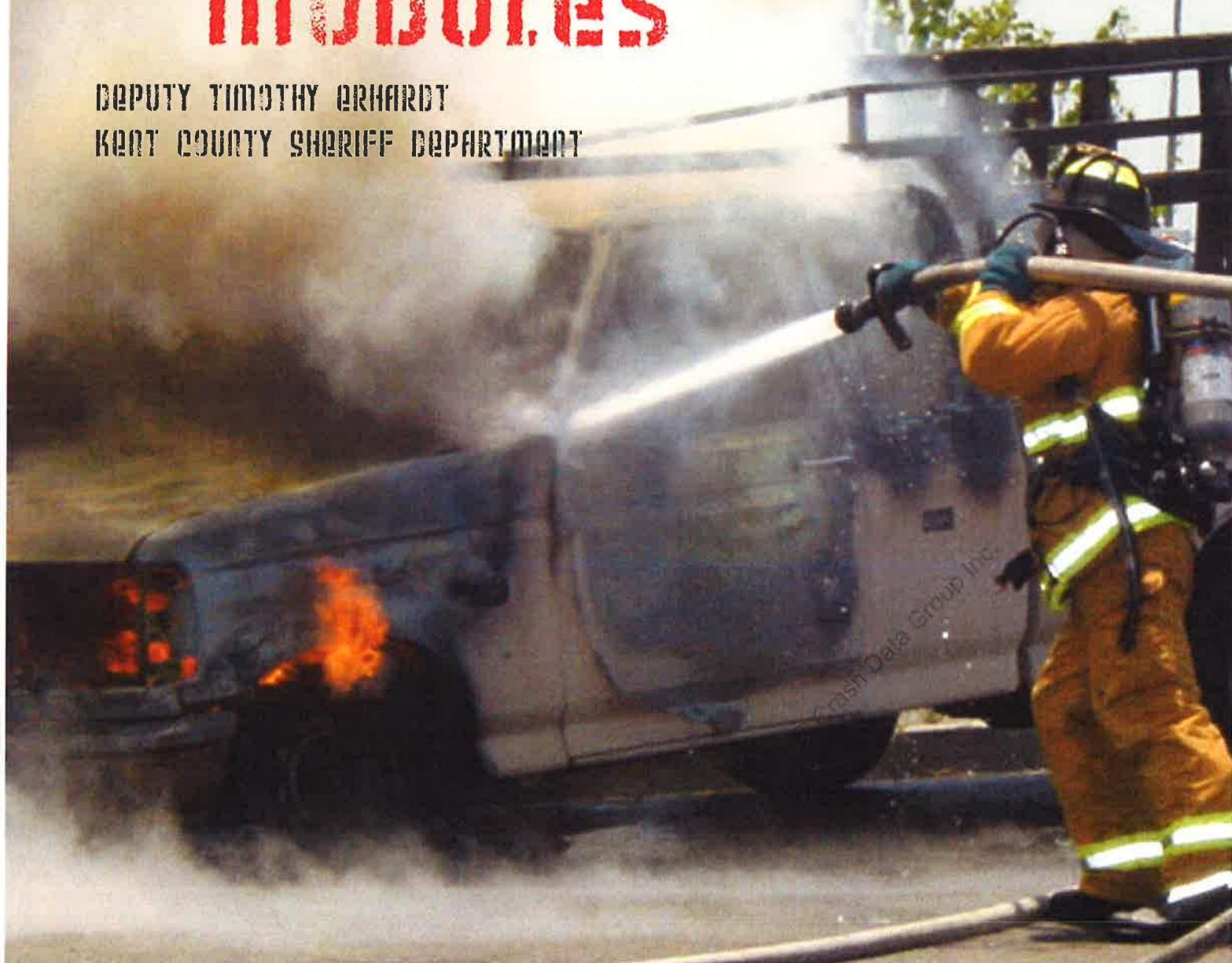
A training day was conducted in Kent County on October 17, 2007. We were going to burn a vehicle to see if we could learn anything. Present at the scene were several accident investigators from the area, both in law enforcement and private practice, a certified mechanic, and a local wrecker company that generously donated the vehicle. Assisting at the scene was the Plainfield Township Fire Department as well as a fire rig from Algoma Township.

Editor's Note: While not intended as a "technical paper," Dep. Erhardt's description of the planning and implementation of this testing/training exercise is a good primer on the obstacles one faces when planning this type of event and the interesting data that can be recovered with persistence and effort.

Figure 1: Test vehicle

The event was staged on the property of the county landfill, in an open field area. The weather was very cooperative and the event was very well attended.

The Question

The control question that brought about this event was how well an airbag module would survive in a vehicle fire. Over the past few years, in the course of investigating crashes, I have seen several vehicles that have burned. Some fires have been small, but others have burned the vehicle almost completely. I have never had a successful download of an ACM from any of these. I asked around to find out if these modules are able to survive in a vehicle fire, but could not find a definitive answer. Initially, I was just going to try to burn a module or two, but a fellow deputy suggested burning an entire car. I found others who thought it would be a good idea, but also wanted to be a part of the event. I then started to do research into putting a training day together, and before I knew it, we were at the landfill burning a car.

Preperation

The first thing I did to make this event a go was to get permission to do it. When I spoke to my supervisor, he was so enthusiastic about it that he wanted to strike the match! After clearing the first hurdle, I then went to the training supervisor with the Plainfield Township Fire Department, Lt. Don Harkes, and asked if he would be interested in helping. He also was more than up to the task. He told me that if I could get a car to burn, he would take care of the location and whatever else needed to be done to make this event safe.

Now that I had permission and a location, all I needed was a car. Finding one was rather difficult. In my initial discussions with Lt. Harkes, he advised that the local wrecker company was very generous in donating autos to his department for training purposes. When I contacted this company and told them of my plan, they told me they might be able to help. I waited for a call from them for a few months, but never heard back. I gave the tow service the guidelines for the vehicle I was looking for, and they contacted me every few weeks to let me know they were still trying to get one that would fit the specifications needed. Finally they called with a vehicle that sounded like it would fit the bill. I was able to meet with them in their lot to survey the vehicle and found that it was just what I was looking for.

Vehicle

The specifics I was seeking in a vehicle were that it has an airbag control module, that we at Kent County would have the ability to download the information from the module, and for the module to have information stored on it. Berry's wrecker company had towed a vehicle from a crash scene earlier in the summer that had an airbag deployment, the owner signed the title over to them,

Figures 2 and 3: Interior of test vehicle

and they were willing to donate it for this training. It was a 2001 Chevrolet Malibu. I was able to successfully download info from the ACM and was even lucky enough that there were 2 different events stored, a deployment and a non-deployment. Now I had a car, permission, a location, and a fire department on board. It was all coming together. I set up the date with a couple of rain dates just in case. When the actual day came, even Mother Nature was on board with us, as she was very cooperative. We had hardly any wind on what turned out to be a perfect October day.

Figures 4-7: Fire sequence

Pre-Burn Set Up
Knowing that this was going to happen, I tried to discern what else might be learned from an incident such as this. It seemed like a big deal to burn a car just to find out if the module would survive, so I wanted to obtain as much information as I could to use as potential reference material in the future.

First, I went to the wrecker lot and performed a Crash Data Retrieval. Once I was able to download the information and see that this car had some good detail, I knew I could continue on with the preparation. The download was printed out and saved to reference later if there was a successful post-burn download.

The next thing I did was take a series of pre-burn photos. When the event was complete, I intended to take the same series of photos so they could be studied side-by-side. The initial photos were taken the day prior to the event with a few more taken at the site.

I requested that event attendees bring extra ACMs to the site so that they could be pulled out of the vehicle during the course of the fire. My reasoning was that if the one built into the car was burned beyond usefulness, we would not know how long it might last before it was ruined. Two spare modules were brought to the scene with attachments to them so they could safely be pulled from the vehicle during the fire. There was also some discussion as to where they should be placed to allow for the best potential results. Due to the set-up of the vehicle, they were both placed as close to the underside of the driver seat as we could, while still allowing for the items to be pulled from the vehicle safely.

It was decided that the first extra module would be pulled after four minutes, and the second would come out after eight minutes. The attachments to the modules were not very long, so I stood as close to the vehicle as I safely could with an eye on a watch, yelling at the proper time increments so a firefighter would pull them from the fire.

I was curious about how the vehicle might change mechanically from a fire. I invited John Shanahan, who is a certified mechanic and has been qualified as an expert witness as such, to the scene. He did a pre-burn survey of the vehicle and went over it a second time, looking for changes, once the fire was out and the vehicle cooled off. I also had the vehicle weighed while on the wrecker as it entered the site and again as it was being hauled away to find out what kind of weight change occurs during a fire.

Once the vehicle was set up and the pre-inspections done, we were ready to go. With all the personnel that were at the site, as well as all the recording equipment there, we had people set up all the way around the vehicle to get different views. A video camera was even set up on top of the fire truck to get more of an aerial view.

All that was left was to watch the burn after the fire department started the fire. Lt. Harkes had arranged for a thermal imaging camera to be onsite so we could get temperature readings as the fire progressed. The department had placed a large amount of newspapers in the back seat of the vehicle. Once people were in position, a road flare was struck and tossed into the back seat amongst the newspaper. Five months of planning had finally come to fruition.

The Fire
Ignition occurred at 0949 hours. It did not take very long before the fire really got going. The fire personnel would not do anything to put out the fire until they got the official okay, as long as scene safety remained in their control. As I stood by watching the clock and gawking, I took several action photos with a digital camera. It was an awesome sight to see the fire start slow and small and quickly overtake and virtually consume the car. As the fire progressed, it seemed very apparent that the interior was going to be totally destroyed.

Lt. Harkes thought it would take about twenty minutes from start to finish, and he was almost exactly right. At the four minute mark, I had the first module pulled and tossed to the side, away from the heat, to be recovered after it cooled. The second module was more of a challenge. As I gave the pull signal for the second at the eight minute mark, the firefighter grabbed the chord and pulled. The wire attachment did not do so well in the fire and broke free of the module. It had to sit through the entire event for us to see if survival

Figures 8 and 9: Close-ups of the airbag control module

was possible.

Now that the fire was going strong and all seemed to be going well except for the mishap of the second removal, we simply waited. At the 14 ½ minute mark, I decided that the fire had done all we needed it to do. I gave the signal to the Lt. and he told his crew to put out the fire. I continued to time the event until virtually all the flames were out and I stopped the clock at 19 minutes and 19 seconds. Occasional flames reared up, but for all intents and purposes, the fire was done.

The Information
It was time to start gathering information. There were many people to help with this. Sgt. Steve LaBrecque from the Grand Rapids Police Department was on scene and had provided the two spare ACMs. He gathered up the module removed at the four minute mark and took it to try and download the info in his patrol car. Prior to doing this, he showed it to several of us who wanted to take a look and it appeared to have faired quite well in the flames. There was some melted plastic from some unknown part of the car that had dripped onto it and was partially covering the receiver, but he pried that off and took it to try the download. He was successful. He advised me that the unit provided him the same info that it had prior to the burn. He also stood by as the eight minute unit was sought after by PTFD. After sifting through the ashes, they located the remains of this module and the results were rather ugly. The module was virtually totally destroyed.

While Sgt. LaBrecque was attempting to download the information, I went to get the info from the thermal camera. I was shocked at how quickly the temperature had climbed early on in the fire. Readings were taken of the vehicle in general and also some occasional readings of specific regions of the car.

Temperature	Time
59°F	Start
550°F	2:20
1000°F	2:30
1200°F	2:39
1400°F	2:54
1200°F	3:26
1400°F	3:39
600°F (vehicle hood)	3:50
1200°F	9:00
1000°F	13:30
175°F (front bumper)	14:20

After PTFD finished extinguishing the flames, it was time to go after the ACM. The vehicle involved is one that has the module located under the passenger front seat. When we approached the car to try to locate it, all we found was a puddle of water. The fire department was able to feel around in the water to find the correct location. They then brought in a jack and lifted the passenger side up so the water would drain toward the driver side and out of the car. The unit was

Figures 10 and 11: The airbag control module from the burn car

Figures 12 and 13: Test vehicle before and after burn

then removed. The exterior was totally blackened, but when we looked at the receiver area, it appeared to be intact. An attempt to download info from the device was attempted at the scene, but Sgt. LaBrecque advised that it showed an error message and would not allow a download. After some discussion, we thought maybe it was too wet so it was left to dry and a download would be attempted later.

Once we finished with the search and recovery of the modules, all that was left to do was to take photos and do the mechanic's re-survey. I had a list of the pre-photos taken and I tried to take the same photos in the same order to compare and contrast the results. Virtually the entire interior was severely damaged from the fire, but the exterior and undercarriage faired much better. The wrecker driver looked at the engine and told me that he thinks it will be salvaged. The undercarriage also seemed to be virtually unaffected.

After the mechanic survey, the vehicle was loaded back onto the wrecker to be taken away. As we were leaving the site, the wrecker parked on the scales for a post burn weight. Most of the water had been drained from the vehicle, but there was still a small amount of standing water in the interior. The weight difference at the scale showed the vehicle to be 20 lbs lighter. The weigh master there told me the error ratio is ±20 lbs. Either way, it was an extremely minimal weight differential.

Results
After the event was completed, I left the original ACM upside down to see if the error message was caused by its wet condition. After one week, I brought it into the office and attempted to do a download, which was a success. The module gave the exact same info as it had before the burn. That led to the question of how bad does the interior of the module look? I tore open the module to look at the interior and there was only some minor plastic melting in the receiver area; the rest seemed to be fully intact. My opening the module appeared to cause more damage to it than the fire.

The mechanic typed up a report with his findings. He noted that during the fire, a rear strut had blown out and the antilock brake wiring had melted. Some other cables showed melting of the insulation around the wiring, and the rubber bushings were partially melted. He noted that all of this was in the rear of the vehicle. The front area of the car around the right tire area was still all intact.

Conclusions
After compiling all the information, I was able to conclude that an ACM can indeed survive a significant fire and still provide valuable data. In looking over the module that did not survive, I came up with a few possible reasons that it was ruined. There was some magnesium burning inside the driver area and I was advised it burns much hotter than normal. It is possible that magnesium came into contact with the module and caused the damage. The more likely possibility is that because the module was not mounted to the frame, but was instead resting on top of the carpet, as the carpet burned, the module was exposed to flames for a longer period of time and on all sides. Also, it seems that while a vehicle fire can drastically change the cosmetic appearance of a vehicle, mechanically a vehicle can remain virtually intact. Overall, the training seemed to be a success.

Attendees
This even was attended by the persons from the following agencies/companies:

Kent County Sheriff Department, Grand Rapids Police Department, Ottawa County Sheriff Department, entwood Police Department, Wyoming Police Department, Michigan State Police Department, GPSBait.com, Magnetic North

I would like to thank the following for assisting in making this training a success:
Chief David Peterson, Lt. Don Harkes
The crew of the Plainfield Township Fire Department
Chief Steve Johnson
The crew of the Algoma Township Fire Department
Sgt. TJ Sikkema- Kent County Sheriff Department
Ken Folkertsma- Kent Career Technical Center
North Kent Transfer Station
Mark and Brad Gillikin and Berry's and Gillikin's Towing service

Figures 14-17: Test vehicle after burn **C**

Case Study:
The "Trampoline Effect" in Reconstruction?

- W. R. "Rusty" Haight and Sean Haight

A ssume you have two cars involved in a crash. Say these two cars are both 1997 Pontiac Grand Ams. They're going to be used in a crash test and both weigh in at 2787lbs (831kg). For this experiment and ultimately, this case problem, the "target" Grand Am is going to be positioned at the point of impact. It will not have any velocity at impact. The bullet Grand Am will strike the target head on with a 100% overlap.

For this case problem, you may assume, as a reliable fact based on instrumentation, that the bullet car will strike the target at 49.9mph (80.3km/h). The target will be spun around and, at rest both will be facing basically the same direction as seen in the photos accompanying this case problem. For identification, the lighter colored car (call the paint "beige" or "gold") is the target, the darker (green) car is the bullet. You may also assume as

Figure 1: Scene photograph

reliable that both cars experienced, in about 102ms, a delta-V of -28.2mph (-45.4km/h).

Since the bullet came in at 49.9mph (80.3km/h) and experienced a delta-V of -28.2mph (-45.4km/h), it's post impact speed is 21.7mph (34.9km/h). The target, stopped at impact, experience a delta-V of -28.2mph (-45.4km/h) but, that's got to be in error, right? How can a car be moved To some speed up from a stop with a "-28.2mph" delta-V? The answer: delta-V is expressed with polarity and following the convention found in SAE J211 ("Instrumentation For Impact Test," rev 1995 and SAE J1733 "Sign Convention for Vehicle Crash Testing") "negative 28.2mph" for a car would be the result of a front-to-rear or, in this case, a negative "x" acceleration.

Now, we know:

Bullet speed at impact: 49.9mph (80.3km/h)   Target speed at impact: stopped
Bullet delta-V: -28.2mph (-45.4km/h)   Target delta-V: -28.2mph (-45.4km/h)
Bullet post impact speed: 21.7mph (34.9km/h)   Target post impact speed: 28.2mph (45.4km/h)[1]

To evaluate this information we might ask ourselves:

(1) Do the delta-Vs make sense, comparing one to the other? Shouldn't they be different since one was stopped?

Answer: yes. The delta-V for each car is, since this was a test, drawn from an accelerometer mounted in each car. Since the cars weigh the same, yes, their delta-Vs should be the same. Whether one is stopped or not isn't relevant. Delta-V is driven by closing velocity not impact velocity. (See: "SAE 980026, "System-Based Energy and Momentum Analysis of Collisions," Schmidt, et al.)

But some may ask: but doesn't "ground effect friction" or whether or not the brakes are set on the target car play a role here? The answer is: no. (See: SAE No. 980298, "Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-End Collisions," Anderson, et al.


Figure 2: Bullet car post-crash photo
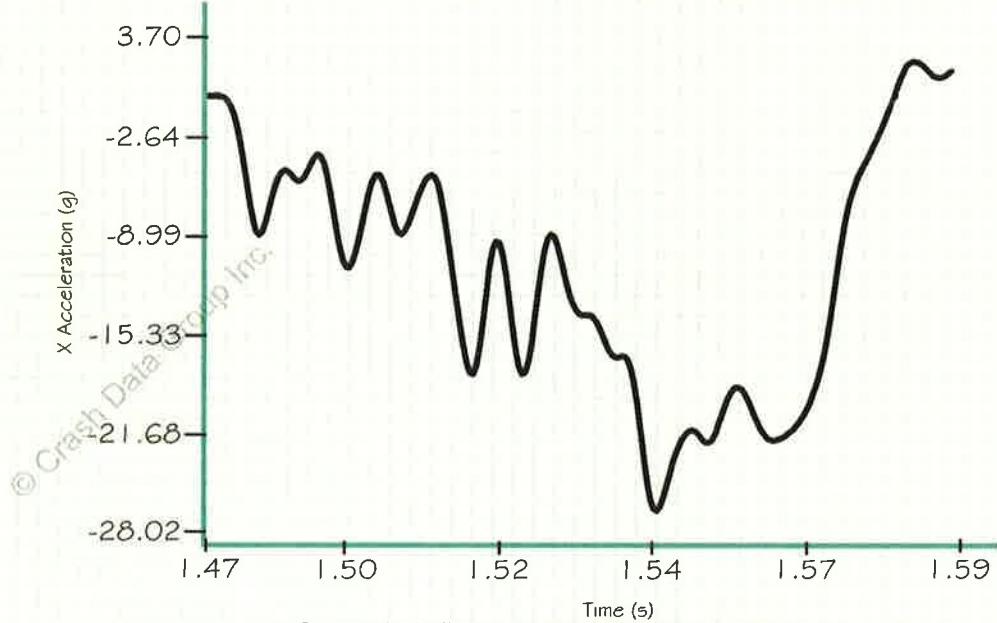
Figure 4: Bullet car accelerometer trace
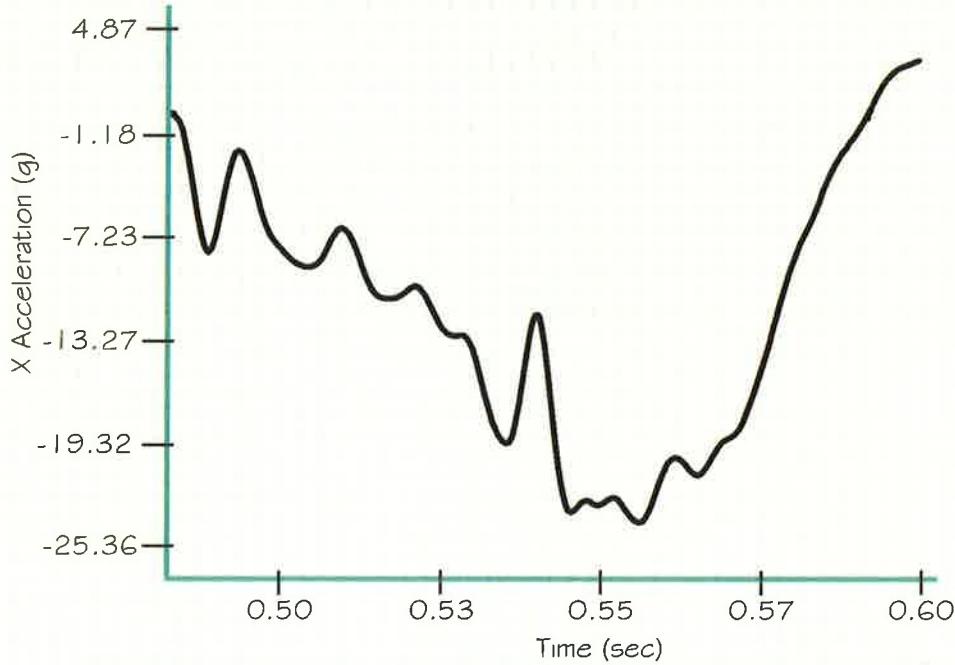
Figure 5: Target car accelerometer trace

(2) The crash is described as a 100% overlap head on collision. Comparing the post impact speeds of the two vehicles, "do they make sense?"

Answer: yes. The target is moving out of the rash faster over the ground (28.2mph) than the bullet (21.7mph) so, yes, the post impact speeds mean the bullet "pushed" the target and didn't "drive through" it or stick to it, pushing it to rest.

(3) That, of course, leads to the question: if they weigh the same...shouldn't they be moving at the same speed post impact?

And that's the focus of this issue's case problem: if we adopt the notion put forth elsewhere that "...street and highway speed collisions between vehicles are almost totally inelastic. The vehicles crush significantly, and do not return the energy that has been expended deforming the metal..."[2] how is it that the target vehicle here, in this crash that, at 49mph is clearly at "street and highway speed," moves out of the crash so much faster than the bullet vehicle?

If we adopt that we can treat collisions at "street and highway" speeds as "inelastic"* then the bullet and target here should have moved out from the crash at the same speed. They did not. For this case problem....explain why not.   **C**

[1] As a vector, for the system we might say that the target's velocity is -28.2mph (-45.4km/h) but, the scalar speed of the center of mass of the target, as a function of this crash, over the ground is 28.2mph.

[2] "Inelastic: a collision in which kinetic energy is not conserved. An example would be a collision of two lumps of clay that stick together after impact." - "Fundamentals of Traffic Crash Reconstruction," IPTM, Daily, et al. P258

Figure 3: Target car post-crash photo

The crash test used for this case problem comes from a series conducted at the Ontario Police College in Aylmer West, Ontario, Canada. These tests were conducted as part of the "Collision Reconstruction" or "Level 4" course conducted in April 2008. The Ontario Police College (OPC) has trained and graduated more than 37,300 police recruits since commencing operation in 1962. Approximately 40,000 other students from a variety of backgrounds including police, civilian employees and Ontario Provincial Government personnel have benefitted from the more than 80 different training courses offered by and through the College instructional staff and guest lecturers. Students from every Canadian province, Britain, the US, the West Indies, Bermuda and the Middle East have attended courses offered at the OPC which is home to one of the largest residential police training facilities in North America. Every year since 2004, the OPC has offered a fully up-to-date and in-depth 3 week long Collision Reconstruction course which, as part of the unique core curriculum, includes multiple full scale crash tests the students use as case problems through which they can apply the skills developed during the larger course. Together with follow-on projects after the core course period, this unique approach has demonstrably improved the skills of those involved in traffic safety efforts on a variety of levels.

The "Level 4" course is coordinated, in part, by the Toronto Police Service and Ontario Provincial Police. The Toronto Police Service, is dedicated to delivering police services, in partnership with allied regional communities, in an effort to keep Toronto one of the best and safest places to live, work and play. The Toronto Police Service employs over 5,000 officers and more than 2,000 civilian staff. We are one of the largest municipal police services in North America, responsible for policing a vibrant city of almost 2.5 million and receiving over 1.7 million calls for service a year. As an organization, the Ontario Provincial Police (O.P.P.) commits to working continually to earn the confidence of the citizens of and visitors to Ontario—a confidence that will not be taken for granted. The O.P.P. fulfills this commitment by providing the best and most professional service, possible, and by striving to build a culture of trust, and open and honest dialogue, with the communities it serves and among the people it employs. The organization commits to creating and sustaining a positive working environment in which all employees have equal opportunity to fulfill their potential within the profession.

Together, the Ontario Police College, Toronto Police Service and Ontario Provincial Police have demonstrated the interest, drive, motivation and skill to develop one of the leading reconstruction course programs available anywhere.

Reconstruction Computation Pad
Collision Magazine

Getting Data from Destroyed SDMs:

Transferring EEPROMs Between Modules

Wade Bartlett

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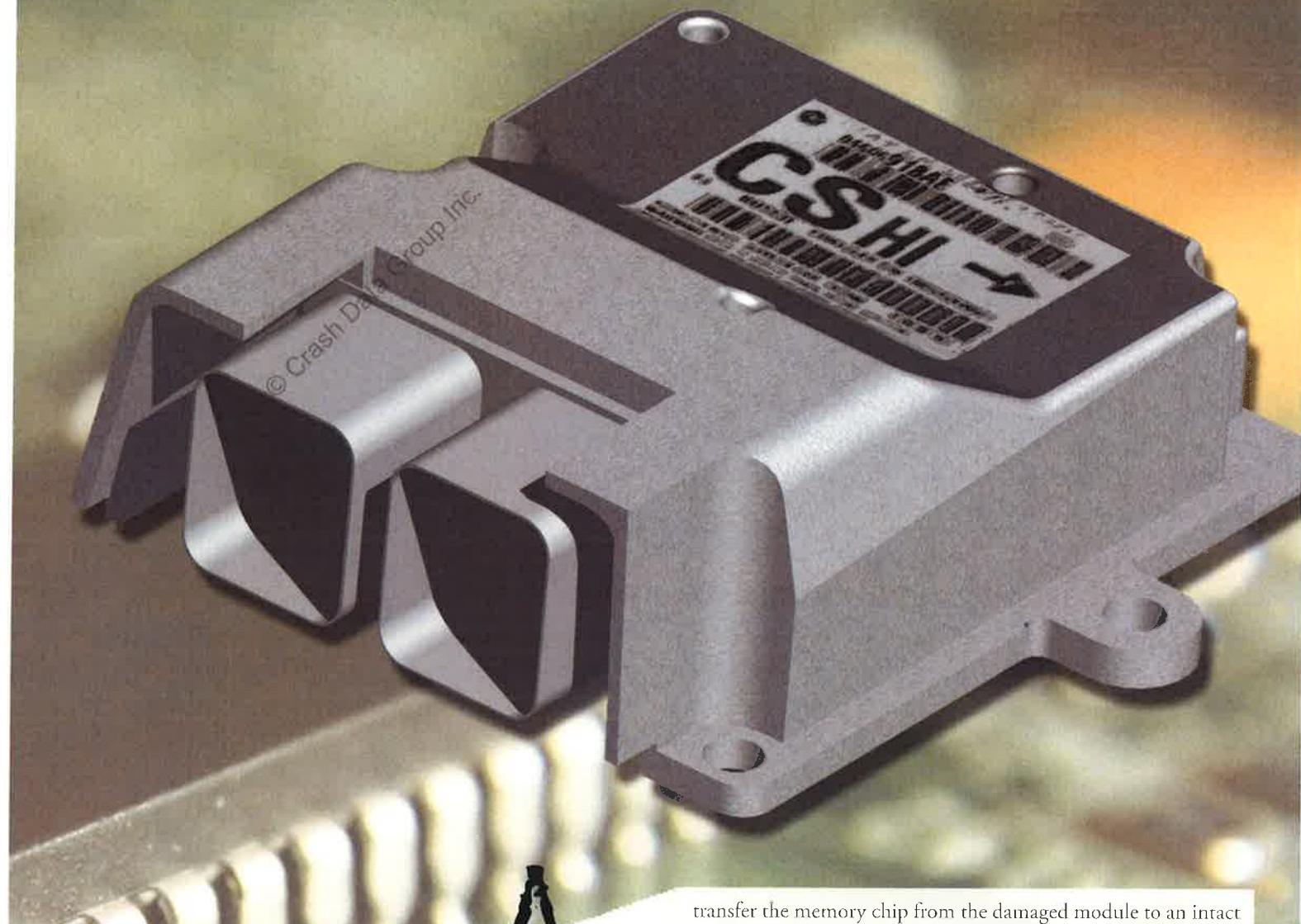
Abstract
Passenger vehicle airbag control modules with event data recording capability have proven to be quite durable. Occasionally, however, fire, water, or mechanical damage can make it impossible to complete a normal download, even if the EEPROM memory chip which might contain recorded information is itself undamaged. In these cases, it may be possible to swap the memory chip from the damaged module into a good surrogate module to interrogate the chip. This article will describe the technique as performed in one case involving a fire-damaged SDM, as well as review some information on EEPROM nomenclature.

Introduction
Occasionally a downloadable airbag control module is too damaged to interrogate through the OBD-II Diagnostic Link Connector or by direct connection to the module. Such damage can be of a mechanical nature (the result of collision or extrication equipment use) but it is more often related to fire in the passenger compartment severe enough to slump the plastic of the module's connector and/or damage the unit's internal circuitry. In these cases, it may be possible to transfer the memory chip from the damaged module to an intact surrogate module for downloading. This paper will describe this transfer process for one case involving a fire-damaged airbag control unit from a 2001 Chevrolet pickup truck using two exemplar modules.

Terminology
The following acronyms and terms will be utilized throughout this article.

Accident Chip: EEPROM removed from the accident vehicle's SDM
EEPROM: Electrically Erasable Programmable Read Only Memory (the memory chip of interest)
Exemplar Chip: EEPROM removed from an exemplar SDM
PCB: Printed Circuit Board
PLCC: Plastic Leaded Chip Carrier (see text for further discussion)
SDM: Sensing and Diagnostic Module (General Motors' name for their airbag control module)
SMT: Surface Mount Technology
**Surrogate Module:** An exemplar SDM with its original EEPROM removed

Figure 1: The heat-damaged accident SDM, with the cover removed.

Crash Background

The subject of this investigation was a 2001 Chevrolet pickup truck which failed to negotiate a bend on a residential street, climbed the curb, and struck a house. The collision damaged the residential gas supply line, causing a fire which destroyed the house, and caused extensive damage to the pickup. The driver was killed. During the subsequent investigation, the airbag control module was recovered from among the front seat debris, and is shown in Figure 1. The module's connector was slumped too much to allow direct interrogation with the Bosch/Vetronix CDR Tool. The investigating agency requested that I attempt to retrieve the data in the module.

Surrogate And Exemplar Modules

Two intact exemplar modules were obtained from vehicles of the same make, model, and model year. Prior to opening the exemplar modules' cases, they were each downloaded with the CDR system, using their original vehicle identification numbers (VINs). They were each downloaded again using the accident vehicle VIN, with no change in the reported data. These were used to verify that the technique did not change the imaged data.

Opening An SDM

The circuit board inside each SDM that I have opened has been affixed in the cover by one or more Torx screws. Some boards have flexible gasket material around their edges, but many newer modules contain boards which have been completely covered after installation with flexible potting material. To access the surface mount components on the board, the potting material was sliced along the edges and picked away from the screw-heads to allow their removal. The board could then be lifted out of the cover, sometimes

requiring slight prying on the connector through the opening in the metal housing, or use of a hooked pick through the screw holes.

Examination revealed that the accident circuit board had been heated enough to flow the solder (which starts to occur at about 400F, or 205C), damaging many electrical connections on the board. The EEPROM, however, appeared to be slightly sooted, but intact. Figure 2 shows some of the main board components.

AChip Primer

Many of us not involved in the computer chip industry commonly understand the EEPROM to be "the chip." That is not true, though, for people in the industry. The
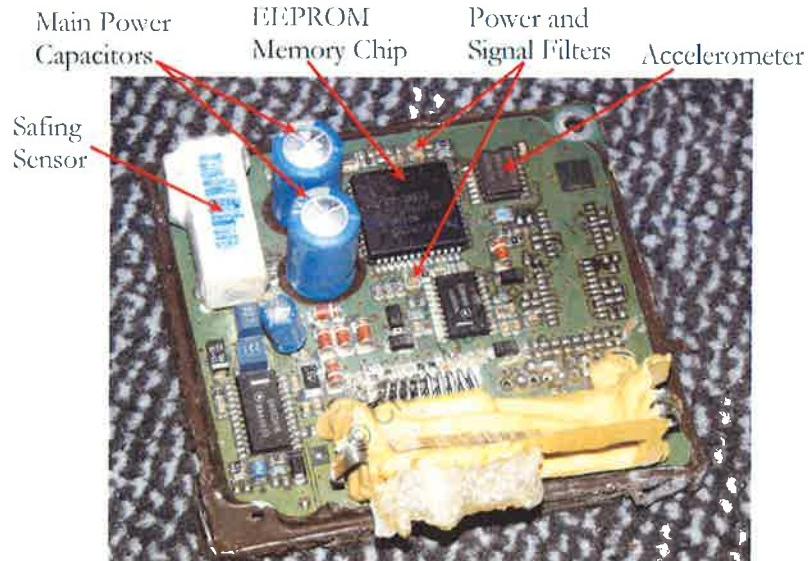

Figure 2: The accident printed circuit board with some major components labeled (ragged potting material edges can be seen on periphery of PCB).

Figure 3: Lifting the EEPROM off the PCB surface while heating from above to flow the solder.

visible outer shell of the EEPROM that we can touch and see is simply a carrier, or package, used to contain the chip (also known as the "die"), and allow convenient installation. Chip packages are either square or rectangular and have 20, 28, 44, 52, 68, or 84 leads per carrier. They can be designed for thru-hole or surface-mount installation, and will include one of a variety of different lead types (gull wing, J-type, C-type, etc). The EEPROMs of interest here are of the 52-pin J-lead SMT PLCC style. This information was used to select suitable sockets. Most recently, I have purchased compact sockets (p/n 19-152-0025) from Emtel Electronics, http://www.emtel.com/ for about $1.25 per unit in lots of 25. The use of a socket allows repeated EEPROM installation and removal in a surrogate board without additional soldering. One should be careful in handling the sockets, though, as rough treatment after installation can break them.

P lacing A Socket
The techniques for removing and relocating surface components are common to the realm of PCB rework, and online guides abound. I strongly recommend that anyone attempting this task themselves practice removing and placing components on one or more "throw-away" boards prior to tackling a valuable or irreplaceable board. Another approach would be to enlist the aid of a person experienced in rework.

The hot air from an industrial heat gun, specifically a Hot Air Gun by Wagner, was directed onto the EEPROM while a slight pressure was applied to the bottom of the chip. Once the solder warmed enough to flow, the chip lifted easily off the board surface. This left 52 solder pads on the board surface with varying amounts of solder still on them. These were cleaned off with solder braid to prepare the area for installation of the socket.

After lifting the EEPROM out of all three modules, one surrogate module was prepared for use as the working platform to download

multiple chips. The main hurdle to overcome when replacing a surface-mount EEPROM with a socket in an SDM is that the socket is physically larger than the EEPROM it replaces. This means that nearby surface components, including the two large capacitors and several smaller capacitors and resistors interfered with the socket's installation, and required relocation.

Each of the two large capacitors had been affixed to the board surface with potting material and had two posts soldered in PCB thru-holes. The top surface potting "glue" was the brown material visible at the base of the large blue capacitors in Figures 1, 2, and 3. A razor was used to cut through some of this potting material and remove some of the potting agent on the reverse side of the PCB at the four through-holes. A soldering iron was held against the bottom side of the PCB, and once the solder flowed, it was possible to pull the capacitors off the board. Though these capacitors' presence or absence should not affect the operation of the module, they were replaced with similarly sized after-market units which had posts long enough to raise them out of the socket's way, as shown in Figure 4.

There were several small rectangular resistors and capacitors along the EEPROM's edge which also interfered with the socket's placement. Though they could most likely be removed without affecting the system's operation, they were all retained. Each of them was relocated either by moving it slightly to one side on its pads, stacking it on top of a paired component, or by turning it up on edge and connecting the elevated edge to the opposite pad with a fine wire which was thin enough to not interfere with the socket.

The socket's base panel was removed to accommodate installation over the top of some of the very thin neighboring components. The panel serves as a structural element to keep opposite sides of the socket parallel, so careful handling was required to make sure
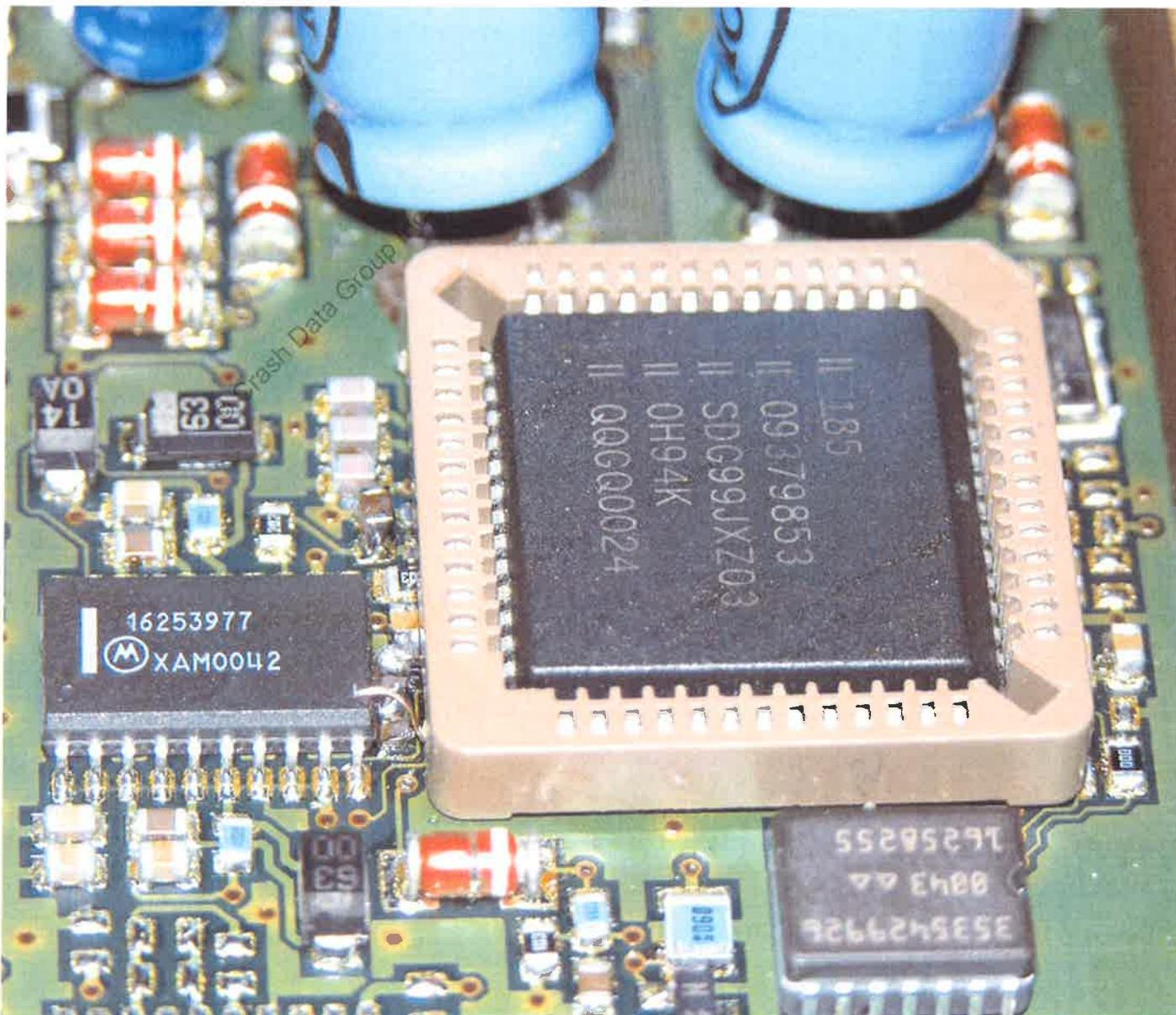
Figure 4: Showing the socket crowding several neighboring components in the surrogate module, with aftermarket capacitors in the background elevated off PCB surface.

it was not distorted during installation. After soldering it in place, the contacts were checked for shorts and cleaned up as required.

Downloading EEPROMs

Once the socket was installed, each of the three EEPROMs discussed earlier (one accident chip and two exemplar chips) was installed and downloaded in turn using its correct VIN. Installation and removal of each chip was accomplished easily and without damage using an inexpensive PLCC Extraction Tool, shown in Figure 5.

The two exemplar EEPROMs yielded downloads identical to their first ones, except that the keycycle data element had incremented by one, as one would hope and expect. The accident EEPROM contained only a Non-Deployment event, but the event data appeared to be consistent with the crash under investigation. Since the keycycles at investigation was not a data element reported by this module, a new event was set in the module by tapping it gently while powered. This confirmed that not only was the Non-Deployment event consistent with the event under investigation, it was set during the module's last keycycle prior to being shipped to me.

Conclusions

This paper has reviewed the steps taken to extract the data from one SDM which was damaged too badly by a post-crash fire to allow a standard direct-to-module download. The key aspect of the exercise was the installation of a PLCC socket in place of the EEPROM memory chip in a surrogate SDM. This allowed repeated installation and removal of EEPROMs for downloading. Furthermore, it was shown that the process of transferring an EEPROM to a surrogate module did not alter the CDR-translation of the data file in either of the two "control" units as compared to the results of downloading them in their original modules. This result gives good confidence in the efficacy of the technique to provide a proper interpretation of a recorded file, even after the EEPROM has been moved to a surrogate module.

Acknowledgements
I would like to thank Chris Rayner of One Second Faster, Inc. for his invaluable assistance and advise regarding chips, sockets, rework, and all things electrical.

Figure 5: Extraction Tool removing EEPROM from socket.

An Alternative Formulation for Symmetric Sine Based Collision Pulse Models
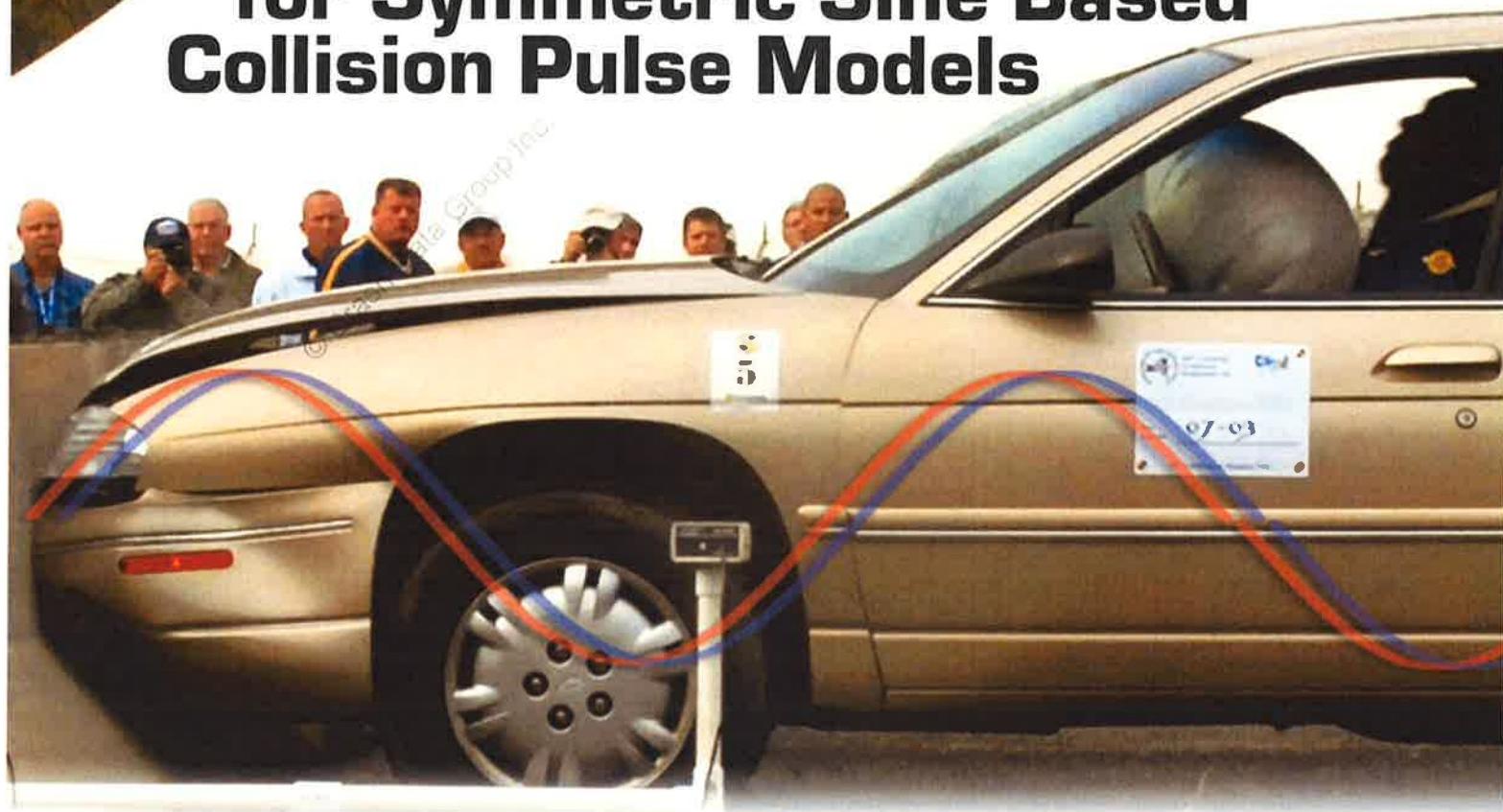
Abstract:
The subject study presents alternate analytical solutions for the kinematic response, the force-deflection response and the force-crush relationships for the half sine and haversine collision pulse models for full-width engagement front to fixed, rigid, massive barrier collision tests. The solutions are developed by implementing the initial and terminal velocity and displacement constraints. The resulting formulation exactly matches the change in speed incurred by the test vehicle and the crush present at the end of the collision duration. The results of the subject formulation are compared with previous formulations through the evaluation of an example problem.

Introduction:
Modeling the acceleration-time history of a motor vehicle undergoing collision involvement is a well-accepted and perhaps commonly utilized practice in the field of accident reconstruction. Knowledge of the shape and form of the acceleration-time history or the use of simple analytical methods for approximating the same are also useful for other endeavors such as the study of occupant kinematics and trauma biomechanics that rely on the use of the collision pulse for exciting the system under study. Two of the commonly used pulse shape approximations fall under the general mathematical classifications of power sine functions with the power being either unity, representing a half sine pulse, or two, representing a haversine pulse. One of the most common sources of data for elucidating the parameters associated with such an analysis is the controlled collision test conducted on the United States (US) New Car Assessment Program (NCAP) testing protocol. In this test, an instrumented vehicle impacts a fixed, massive, rigid instrumented barrier in the form of a full width frontal engagement impact at a known impact speed.

The underlying terminology and interrelationship between the various parameters defining the sine function have been previously discussed by the authors [Singh and Perry, 2007]. In brief, half of the period of the full sinusoid is used for modeling the duration of the collision, T_{impact}. The circular frequency, ω, is thus equal to π/T_{impact}. The kinematic equations for a half sine pulse approximation, prior to substitution of desired conditions to define the constants of integration, are given by equations (1a-c).

$$\ddot{x}(t) = A_p \cdot \sin(\omega t)$$

[Eqn. 1a]

$$\dot{x}(t) = -\frac{A_p}{\omega} \cdot \cos(\omega t) + C_1$$

[Eqn. 1b]

$$x(t) = -\frac{A_p}{\omega^2} \cdot \sin(\omega t) + C_1 \cdot t + C_2$$

[Eqn. 1c]

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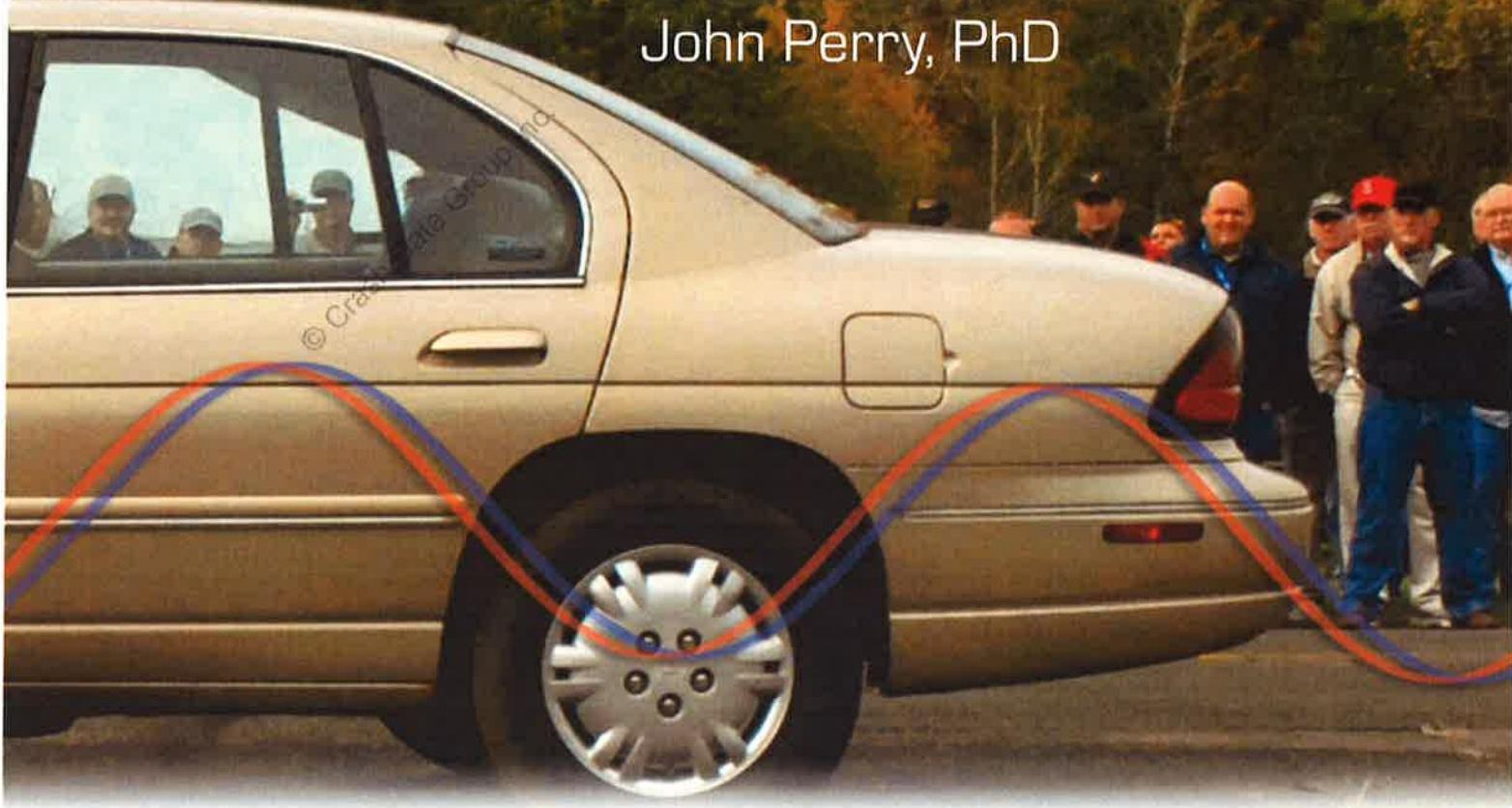
Similarly, for the haversine model, the kinematic solution is given by equations (2a-c).

$$\ddot{x}(t) = A_p \cdot \sin^2(\omega t)$$

[Eqn. 2a]

$$\dot{x}(t) = A_p \left(\frac{t}{2} - \frac{\sin(2\omega t)}{4\omega} \right) + C_1$$

[Eqn. 2b]

$$x(t) = A_p \left(\frac{t^2}{4} + \frac{\cos(2\omega t)}{8\omega^2} \right) + C_1 t + C_2$$

[Eqn. 2c]

In both sets of equations the term A_p is the amplitude of the function, ω is the circular frequency and C_1 and C_2 are constants of integration. The use of a combination of boundary or internal conditions allows for solving for some or all of these parameters in terms of other parameters associated with the collision event. Huang [2002] proposed a solution in which the initial velocity at time $t = 0$, the known zero valued displacement at time $t = 0$, the peak displacement and the time of the peak displacement to rewrite the kinematic equations. The resulting equations were then numerically integrated using the Newton-Raphson method. Varat and Husher [2002] used the initial displacement condition, the measured collision duration and two boundary conditions on the velocity solution (i.e. v_o at time $t = 0$ and v_f at time $t = T_{impact}$) to solve the two sets of equations such that all parameters were analytically formed in terms of the collision duration and the change in speed incurred by the test vehicle. The authors followed this method in their analysis of the Federal Motor Vehicle Safety Standard (FMVSS) 208 sled test [Singh and Perry, 2005] and in terms of determining the implications of the use of half sine and haversine collision pulse shapes on the force-displacement and force-crush response [Singh and Perry, 2007]. This formulation, as expected, resulted in the exact matching of the initial and final velocity of the test vehicle. For the implemented example, however, there was a discrepancy between the measured displacement at the end of the collision duration (i.e. crush depth) and the predicted crush depth based on the two models. In reviewing the results of this previous study, the authors determined that a formulation could be developed that matched the total change in velocity incurred by the test vehicle as well as the crush present at the terminus of the collision.

Objectives:
The objectives of the subject study were the development of an alternate solution for the half sine and haversine collision pulse models that matched the total change in velocity and crush depth present for vehicles tested under NCAP protocols and to elucidate the force-displacement and force-crush relationships.

Analytical Methods:
The natural boundary conditions on equations (1a) and (2a) are zero acceleration at the start and at the terminus of the collision event. Instead of defining the collision duration, and thus the circular frequency, as in the prior formulation, the boundary displacement and velocity constraints were defined. Specifically, these constraints are the initial velocity at time t = 0, the final velocity at time t = π/ω, zero displacement at time t = 0 and the crush depth δ_s at time t = π/ω.

Half sine model formulation:
Substitution of the velocity and displacement boundary conditions into equations (1b) and (1c) respectively results in the following four equations. The unknowns are the pulse amplitude, the circular frequency and the constants of integration.

$$\dot{x}(0) = v_o = -\frac{A_p}{\omega} \cdot \cos(\omega \cdot 0) + C_1$$

[Eqn. 3a]

$$\dot{x}\left(\frac{\pi}{\omega}\right) = v_f = -\frac{A_p}{\omega} \cdot \cos\left(\omega \cdot \frac{\pi}{\omega}\right) + C_1$$

[Eqn. 3b]

$$x(0) = 0 = -\frac{A_p}{\omega^2} \cdot \sin(\omega \cdot 0) + C_1 \cdot 0 + C_2$$

[Eqn. 3c]

$$x\left(\frac{\pi}{\omega}\right) = \delta_s = -\frac{A_p}{\omega^2} \cdot \sin\left(\omega \cdot \frac{\pi}{\omega}\right) + C_1 \cdot \frac{\pi}{\omega} + C_2$$

[Eqn. 3d]

Equation (3c), by inspection, reduces to $C_2 = 0$. Substitution of this result into equation (3d) and solving for the first constant of integration in terms of the other system parameters results in equation (4).

$$C_1 = \frac{\omega}{\pi} \cdot \delta_s$$

[Eqn. 4]

Equation (4) is then substituted into equation (3b), resulting in equation (5) and also when substituted into equation (3a), results in equation (6).

$$v_f = \frac{A_p}{\omega} + \frac{\omega}{\pi} \cdot \delta_s$$

[Eqn. 5]

$$v_o = -\frac{A_p}{\omega} + \frac{\omega}{\pi} \cdot \delta_s$$

[Eqn. 6]

Equations (5) and (6) are then solved simultaneously to determine the closed form analytical solutions for the circular frequency and amplitude in terms of the known system parameters. The results are given by equations (7) and (8), respectively.

$$A_p = \frac{\pi}{4\delta_s}\left(v_f^2 - v_o^2\right)$$

[Eqn. 7]

$$\omega = \frac{\pi}{2\delta_s}\left(v_o + v_f\right)$$

[Eqn. 8]

Substitution of equation (8) into equation (4) results in the solution for the first constant of integration in terms of the known system parameters.

$$C_1 = \frac{1}{2}\left(v_o + v_f\right)$$

[Eqn. 9]

Substitution of equations (7-9) and the solution for the second constant of integration into equations (1a-c) results in the final alternative set of solutions for the kinematic response associated with the half sine collision pulse model.

$$\ddot{x}(t) = \frac{\pi}{4\delta_s}\left(v_f^2 - v_o^2\right) \cdot \sin\left(\frac{\pi t}{2\delta_s}\left(v_o + v_f\right)\right)$$

[Eqn. 10a]

$$\dot{x}(t) = \frac{1}{2}\left(v_o - v_f\right) \cdot \cos\left(\frac{\pi t}{2\delta_s}\left(v_o + v_f\right)\right) + \frac{1}{2}\left(v_o + v_f\right)$$

[Eqn. 10b]

$$x(t) = -\left(\frac{\delta_s}{\pi} \cdot \frac{v_f - v_o}{v_o + v_f}\right) \cdot \sin\left(\frac{\pi t}{2\delta_s}\left(v_o + v_f\right)\right) + \frac{t}{2}\left(v_o + v_f\right)$$

[Eqn. 10c]

The temporal limits are given by equation (11).

$$0 \leq t \leq T_{impact} = \frac{\pi}{\omega} = \frac{2\delta_s}{v_o + v_f}$$

[Eqn. 11]

The coefficient of restitution [Singh and Perry, 2007] is defined as per equation (12).

$$\varepsilon = -\frac{v_f}{v_o}$$

[Eqn. 12]

The kinematic response for this model can thus be rewritten in terms of the coefficient of restitution.

$$\ddot{x}(t) = \frac{\pi v_o^2}{4\delta_s}\left(\varepsilon^2 - 1\right) \cdot \sin\left(\frac{\pi v_o t}{2\delta_s}(1 - \varepsilon)\right)$$

[Eqn. 13a]

$$\dot{x}(t) = \frac{v_o}{2}(1 + \varepsilon) \cdot \cos\left(\frac{\pi v_o t}{2\delta_s}(1 - \varepsilon)\right) + \frac{v_o}{2}(1 - \varepsilon)$$

[Eqn. 13b]

$$x(t) = \left(\frac{\delta_s}{\pi} \cdot \frac{(1 + \varepsilon)}{(1 - \varepsilon)}\right) \cdot \sin\left(\frac{\pi v_o t}{2\delta_s}(1 - \varepsilon)\right) + \frac{v_o t}{2}(1 - \varepsilon)$$

[Eqn. 13c]

The magnitude of the collision force is the absolute value of the multiple of the mass and the acceleration magnitude. The equivalent of the latter, for the subject formulation, is achieved by reversing the signs of the squares of the velocity terms in equation (10a). The corresponding effect on equation (13a) would be to reverse the signs of the terms associated with the coefficient of restitution in the parenthesis.

$$\left|F(t)\right| = m\left|\ddot{x}(t)\right| = \frac{\pi m v_o^2}{4\delta_s}\left(1-\varepsilon^2\right)\cdot\sin\left(\frac{\pi v_o t}{2\delta_s}(1-\varepsilon)\right)$$

[Eqn. 14]

The analytical relationship between the magnitude of the collision force and the displacement is determined by dividing equation (14) by equation (13c). This equation is not readily reducible to a simple form from that shown by equation (15).

$$\frac{\left|F(t)\right|}{x(t)} = \frac{\frac{\pi m v_o^2}{4\delta_s}\left(1-\varepsilon^2\right)\cdot\sin\left(\frac{\pi v_o t}{2\delta_s}(1-\varepsilon)\right)}{\left(\frac{\delta_s}{\pi}\cdot\frac{(1+\varepsilon)}{(1-\varepsilon)}\right)\cdot\sin\left(\frac{\pi v_o t}{2\delta_s}(1-\varepsilon)\right)+\frac{v_o t}{2}(1-\varepsilon)}$$

[Eqn. 15]

The peak displacement occurs at the time when the velocity is equal to zero. Setting equation (13b) and solving for this time results in the following:

$$t = \frac{2\delta_s}{\pi v_o(1-\varepsilon)}\cdot\arccos\left(\frac{\varepsilon-1}{\varepsilon+1}\right)$$

[Eqn. 16]

Substitution of this solution into equation (13c) results in the analytical form for the peak displacement.

$$\delta_d = \frac{\delta_s}{\pi}\left(\left(\frac{(1+\varepsilon)}{(1-\varepsilon)}\right)\cdot\sin\left(\arccos\left(\frac{\varepsilon-1}{\varepsilon+1}\right)\right)+\arccos\left(\frac{\varepsilon-1}{\varepsilon+1}\right)\right)$$

[Eqn. 17]

The relationship between the peak collision force (occurring at half the collision duration) and the crush present (occurring at the end of the collision duration) is given by equation (18).

$$\frac{\left|F(t)\right|}{\delta_s} = \frac{\pi m v_o^2}{4\delta_s^2}\left(1-\varepsilon^2\right)$$

[Eqn. 18]

Haversine model formulation. Substitution of the desired velocity and displacement constraints into equations (2b) and (2c) respectively results in the following:

$$\dot{x}(0) = v_o = A_p\left(\frac{0}{2}-\frac{\sin(2\omega\cdot0)}{4\omega}\right)+C_1$$

[Eqn. 19a]

$$\dot{x}\left(\frac{\pi}{\omega}\right) = v_f = A_p\left(\frac{\pi}{2\omega}-\frac{\sin\left(2\omega\frac{\pi}{\omega}\right)}{4\omega}\right)+C_1$$

[Eqn. 19b]

$$x(0) = 0 = A_p\left(\frac{0^2}{4}+\frac{\cos(2\omega\cdot0)}{8\omega^2}\right)+C_1\cdot0+C_2$$

[Eqn. 19c]

$$x\left(\frac{\pi}{\omega}\right) = \delta_s = A_p\left(\frac{\pi^2}{4\omega^2}+\frac{\cos\left(2\omega\cdot\frac{\pi}{\omega}\right)}{8\omega^2}\right)+C_1\cdot\frac{\pi}{\omega}+C_2$$

[Eqn. 19d]

Equation (19a) reduces to $C_1 = v_o$. Substituting this result into equation (19b) and simplifying the result.

$$A_p = \frac{2\omega}{\pi}\left(v_f-v_o\right)$$

[Eqn. 20]

Simplifying equations (19c) and (19d):

$$C_2 = -\frac{1}{8}\cdot\frac{A_p}{\omega^2}$$

[Eqn. 21]

$$\delta_s = A_p\left(\frac{2\pi^2+1}{8\omega^2}\right)+v_o\cdot\frac{\pi}{\omega}+C_2$$

[Eqn. 22]

Equations (20-22) represent three equations with the three unknowns A_p, ω and C_2. These equations can be solved simultaneously to yield solutions for the unknowns in terms of the known system parameters:

$$A_p = \frac{1}{\delta_s}\left(v_f-v_o\right)\left(v_f+v_o\right)$$

[Eqn. 23]

$$C_2 = -\frac{\delta_s}{2\pi^2}\cdot\frac{v_f-v_o}{v_f+v_o}$$

[Eqn. 24]

$$\omega = \frac{\pi\left(v_f+v_o\right)}{2\delta_s}$$

[Eqn. 25]

Substitution of these results into equations (2a-c) provides the solution for the kinematic response for the subject alternative haversine formulation.

$$\ddot{x}(t) = \frac{1}{\delta_s}\left(v_f-v_o\right)\left(v_f+v_o\right)\cdot\sin^2\left(\frac{\pi t\left(v_f+v_o\right)}{2\delta_s}\right)$$

[Eqn. 26a]

$$\dot{x}(t) = \frac{t}{2\delta_s}\left(v_f-v_o\right)\left(v_f+v_o\right)-\frac{1}{2\pi}\left(v_f-v_o\right)\cdot\sin\left(\frac{\pi t\left(v_f+v_o\right)}{\delta_s}\right)+v_o$$

[Eqn. 26b]

$$x(t) = \frac{t^2}{4\delta_s}\left(v_f-v_o\right)\left(v_f+v_o\right)+\frac{\delta_s}{2\pi^2}\cdot\left(\frac{v_f-v_o}{v_f+v_o}\right)\cdot\left(\cos\left(\frac{\pi t\left(v_f+v_o\right)}{\delta_s}\right)-1\right)+v_o t$$

[Eqn. 26c]

The temporal limits are given by equation (27).

$$0 \le t \le T_{impact} = \frac{\pi}{\omega} = \frac{2\delta_s}{v_f + v_o} = \frac{2\delta_s}{v_o(1-\varepsilon)}$$

[Eqn. 27]

Following the derivation methodology from the prior solution, we rewrite equations (26a-c) in terms of the coefficient of restitution.

$$\ddot{x}(t) = -\frac{v_o^2}{\delta_s}(1+\varepsilon)(1-\varepsilon)\cdot\sin^2\left(\frac{\pi v_o t(1-\varepsilon)}{2\delta_s}\right)$$

[Eqn. 28a]

$$\dot{x}(t) = \frac{v_o}{2\pi}(1+\varepsilon)\cdot\sin\left(\frac{\pi v_o t(1-\varepsilon)}{\delta_s}\right) - \frac{v_o^2 t}{2\delta_s}(1+\varepsilon)(1-\varepsilon) + v_o$$

[Eqn. 28b]

$$x(t) = -\frac{v_o^2 t^2}{4\delta_s}(1+\varepsilon)(1-\varepsilon) - \frac{\delta_s}{2\pi^2}\cdot\left(\frac{1+\varepsilon}{1-\varepsilon}\right)\cdot\left(\cos\left(\frac{\pi v_o t(1-\varepsilon)}{\delta_s}\right)-1\right) + v_o t$$

[Eqn. 28c]

The magnitude of the collision force is given by equation (29).

$$|F(t)| = m\ddot{x}(t) = \frac{mv_o^2}{\delta_s}(1+\varepsilon)(1-\varepsilon)\cdot\sin^2\left(\frac{\pi v_o t(1-\varepsilon)}{2\delta_s}\right)$$

[Eqn. 29]

The relationship between force and deflection is parametric in time and is not reducible in regards to the ratio of equation (29) with respect to equation (28c).

$$\frac{|F(t)|}{x(t)} = \frac{\frac{mv_o^2}{\delta_s}(1+\varepsilon)(1-\varepsilon)\cdot\sin^2\left(\frac{\pi v_o t(1-\varepsilon)}{2\delta_s}\right)}{-\frac{v_o^2 t^2}{4\delta_s}(1+\varepsilon)(1-\varepsilon) - \frac{\delta_s}{2\pi^2}\cdot\left(\frac{1+\varepsilon}{1-\varepsilon}\right)\cdot\left(\cos\left(\frac{\pi v_o t(1-\varepsilon)}{\delta_s}\right)-1\right) + v_o t}$$

[Eqn. 30]

The temporal location of the peak displacement is when the velocity, given by equation (28c), is equal to zero. The resulting equation is non-algebraic in time and thus a closed form analytical solution is not readily apparent. This is a common finding for all power sine formulations in which the power of the sine function is greater than one. The peak displacement, however, can be readily determined numerically for any specific collision test under study. The crush depth, for the subject formulation is taken as being given based upon the subject alternate formulation. The peak force occurs at half the collision duration (based upon the form of the acceleration function). Substitution of this temporal location into equation (29) shows that the magnitude of the peak force is:

$$|F_{peak}| = \frac{mv_o^2}{\delta_s}(1+\varepsilon)(1-\varepsilon)$$

[Eqn. 31]

This solution is also determinable from noting that the sin² function reaches a maximum value, that being unity, when the argument of the sine operator is π/2. It should also be noted that equation (31) is simply the amplitude of the collision pulse multiplied by the mass of the test vehicle. The relationship between the magnitude of the peak collision force and the crush present is thus simply:

$$\frac{|F_{peak}|}{\delta_s} = \frac{mv_o^2}{\delta_s^2}(1+\varepsilon)(1-\varepsilon)$$

[Eqn. 32]

Methods and Materials

All instrumentation data was obtained from the National Highway Transportation Safety Administration (NHTSA) through the Load Cell Analysis (LCA) software program and interface (NHTSA; v1.6.4.1). All accelerometer and barrier load cell time history data was automatically filtered using a SAE CFC60 filter. The impact speed and vehicle mass were determined from reviewing the Test Specification sheet associated with each test under evaluation. The quantitative data was imported as a series of ASCII files from the LCA program into a spreadsheet program (Excel 2007; Microsoft Corporation; Redmond, Washington, USA). The data was then converted into consistent units in the MKS unit system. The predicted kinematic response for each model was evaluated on data available from each instrument. The resultant predicted kinematic time histories and force-deflection data were imported into a second program for visualization of the results (Sigma Plot v.7.101; SPSS; Chicago, Illinois, USA).

Worked Example

We again consider NHTSA test number v3188 – the assessment test for frontal impact protection for a 2000 Honda Accord 4-door sedan. The mass of the vehicle, as tested, was 1584 kg. The velocity of the test vehicle at impact was measured as being 56.3 KPH. The final velocity, that being the velocity at the end of the separation phase, was taken as being the maximum magnitude negative velocity. The rationale behind this approach is that the magnitude of the velocity of the test vehicle at all times following separation will decrease secondary to the action of dissipative drag on the test vehicle. The negative velocity at the end of the separation phase will be at a maximum secondary to the completion of the restoration of the portion of the absorbed energy that was not dissipated. The velocity at the end of the separation phase depended on the instrumentation from which such data was being obtained. For the subject test, data could be obtained through a balance of forces between the vehicle and the load cell barrier (momentum solution) or by use of the accelerometer data. The latter was available from an accelerometer mounted on the left rear crossmember, the right rear crossmember and from a redundant accelerometer located at the right rear crossmember. The results for the initial velocity, final velocity, actual duration, predicted duration and predicted circular frequency are given in Table 1. The circular frequency for both models is the same as per equations (8) and (25). Thusly, the predicted impact duration for each model will be the same. The actual closing speed, separation speed and crush are inputs into both models and thus are exactly matched. The amplitude of each pulse model differs in accordance with equations (7) and (23).

The acceleration-time histories, based upon each source of data and each of the two modeling methods is shown in Figure 1. The velocity-time histories, based upon each source of data and each of the two modeling methods is shown in Figure 2. The displacement-time histories, based upon each source of data and each of the two modeling methods is shown in Figure 3.

For this specific test, the predicted collision duration was substantially shorter than the determination of the collision duration based upon the temporal location of the peak negative velocity (relative difference of 39 to 43%). Consequently, the cyclic frequency was greater than that which could be determined by the temporal location of the peak negative velocity (24.47 to 27.41 Hz). The expected modeled pulse amplitudes were greater for the haversine model than the half sine model. Finally, the actual and modeled force-deflection responses are shown in Figure 4.

For this test, the peak displacement was underestimated by both models, but the crush depth was matched given that this parameter served as an input into the model. Both the half sine and haversine models were non-linear in regards to the totality of the loading and unloading phases. Also, as expected, the haversine model had an initial region during the loading phase that was less steep (based upon the visual indication of the tangent stiffness) than that of the half sine model. This was followed by a region of increasing slop and resulted in a larger predicted peak force. This response mirrored the responses observable in the acceleration-time history with the haversine pulse having a greater degree of weight centrally versus in the periphery of the curve when compared with the half sine pulse and because of the requisite equal area under the curve (as per the equivalent change in velocity modeled) having a greater amplitude.

Discussion

The alternative forms of the equations for the half sine and haversine collision pulses for modeling NCAP and FMVSS 208D (accelerometer based data only) collision

Source	v_0 (m/sec)	v_f (m/sec)	$T_{impact-actual}$ (msec)	δ_s (m)	ω (Hz)	$T_{impact-predicted}$ (msec)	A_{p-half} (m/sec^2)	A_{p-have} (m/sec^2)
Momentum	15.6389	-2.4110	128.4	0.5122	40.57	77.44	-366.1	-467.3
SELR	15.6389	-2.6888	118.3	0.6202	32.80	95.78	-300.6	-382.7
SERR	15.6389	-2.8483	114.8	0.6108	32.89	95.51	-304.1	-387.1
SERR*	15.6389	-2.8327	114.6	0.6124	32.85	95.64	-303.4	-386.3

Table 1. Velocity and displacement constraints for each source of data and the predicted impact duration, circular frequency and modeled pulse amplitude for each model.
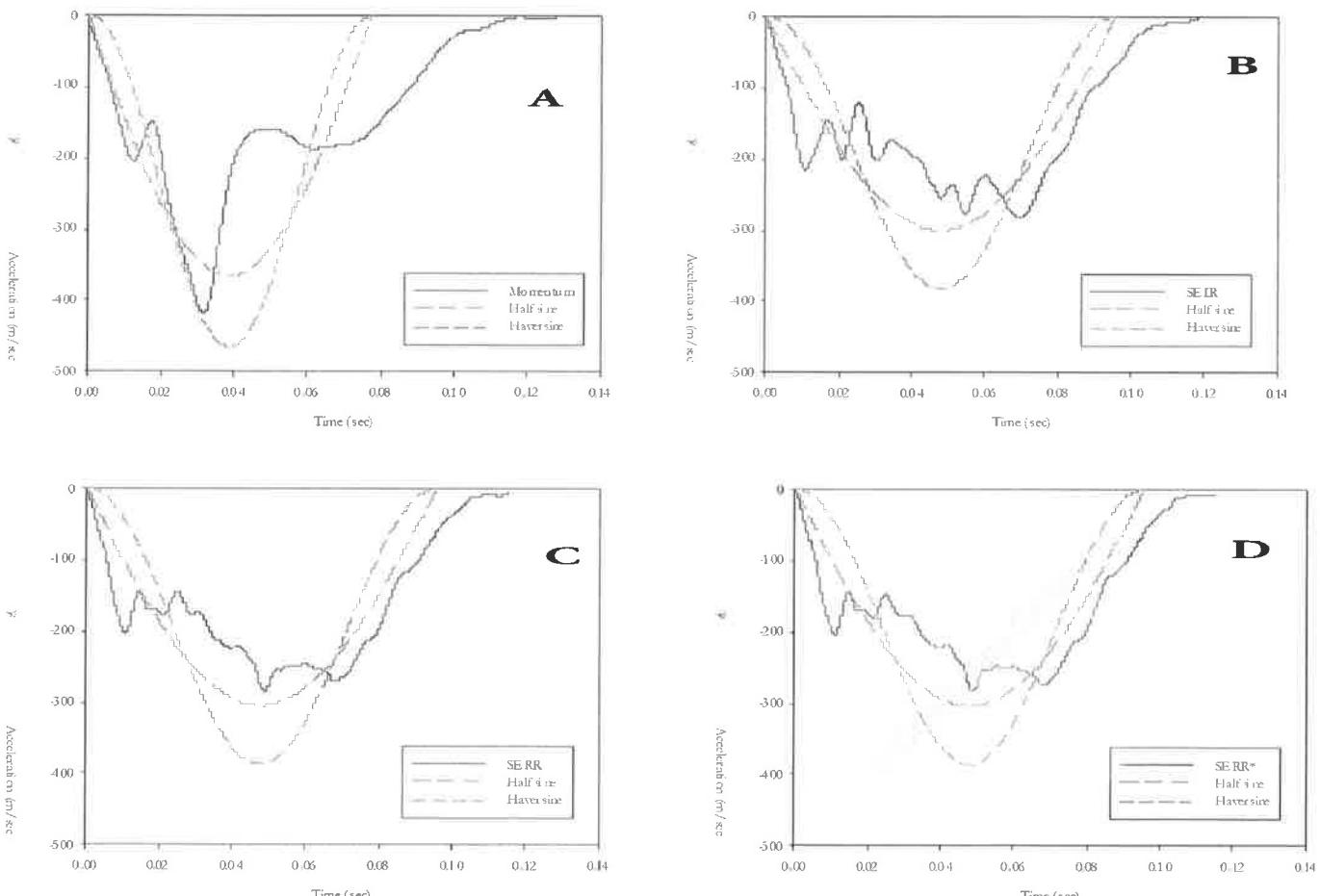
Figure 1. Acceleration-time histories for the momentum (A), left rear crossmember accelerometer (B), right rear crossmember accelerometer (C) and redundant right rear crossmember accelerometer (D) solutions.
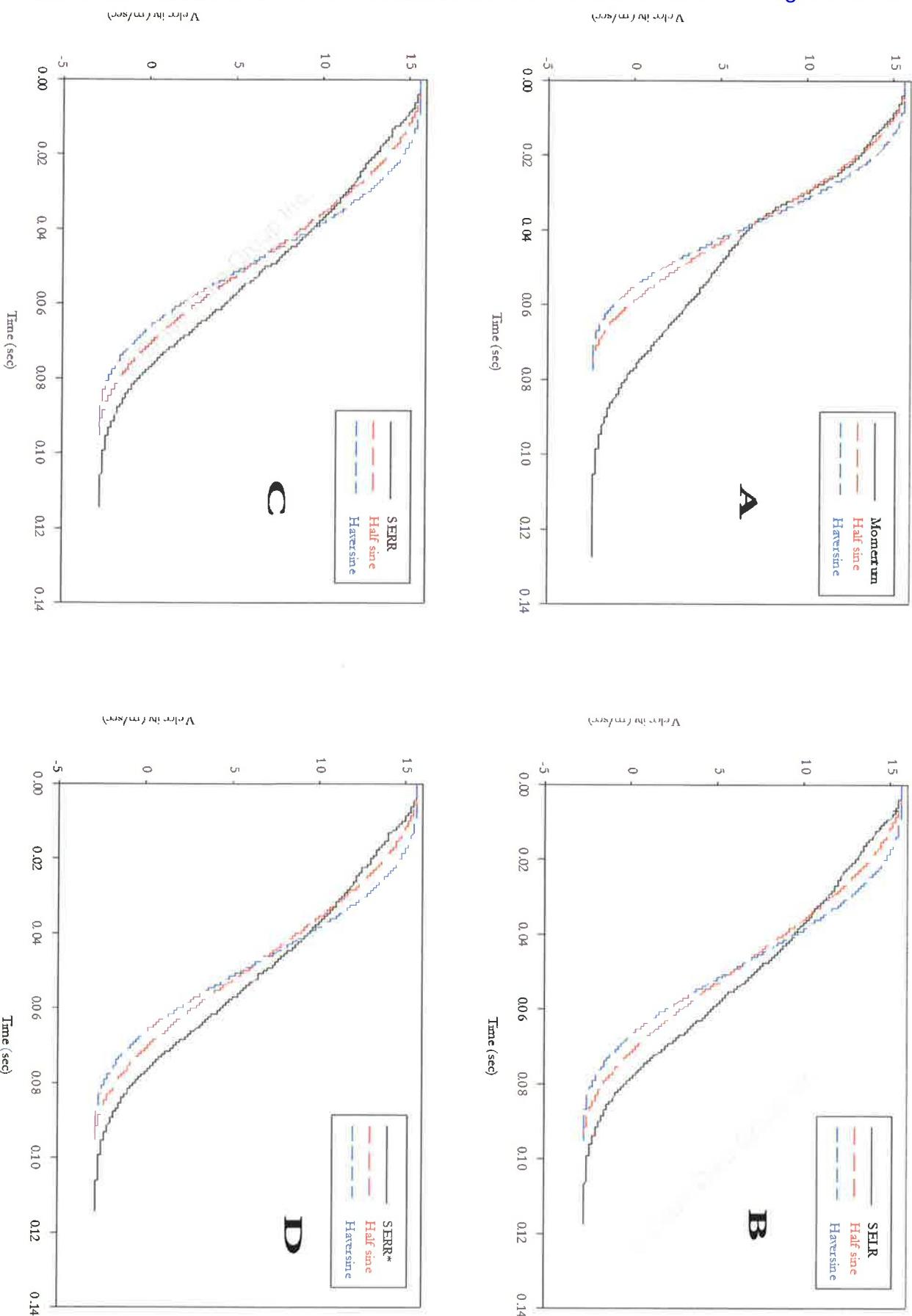
Figure 2. Velocity-time histories for the momentum (A), left rear crossmember accelerometer (B), right rear crossmember accelerometer (C) and redundant right rear crossmember acceler-ometer (D) solutions.
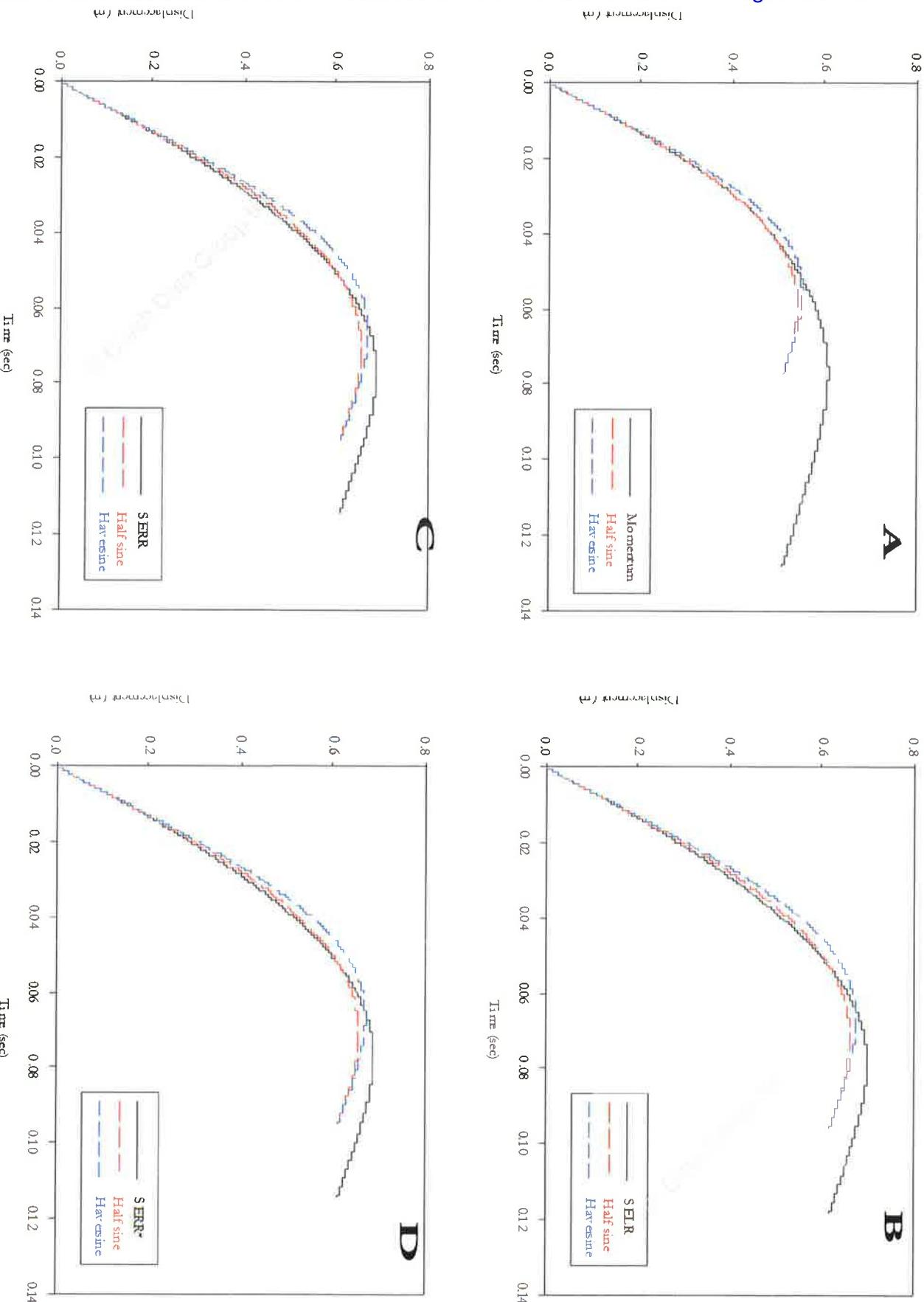
Figure 3. Displacement-time histories for the momentum (A), left rear crossmember accelerometer (B), right rear crossmember accelerometer (C) and redundant right rear crossmember accelerometer (D) solutions.
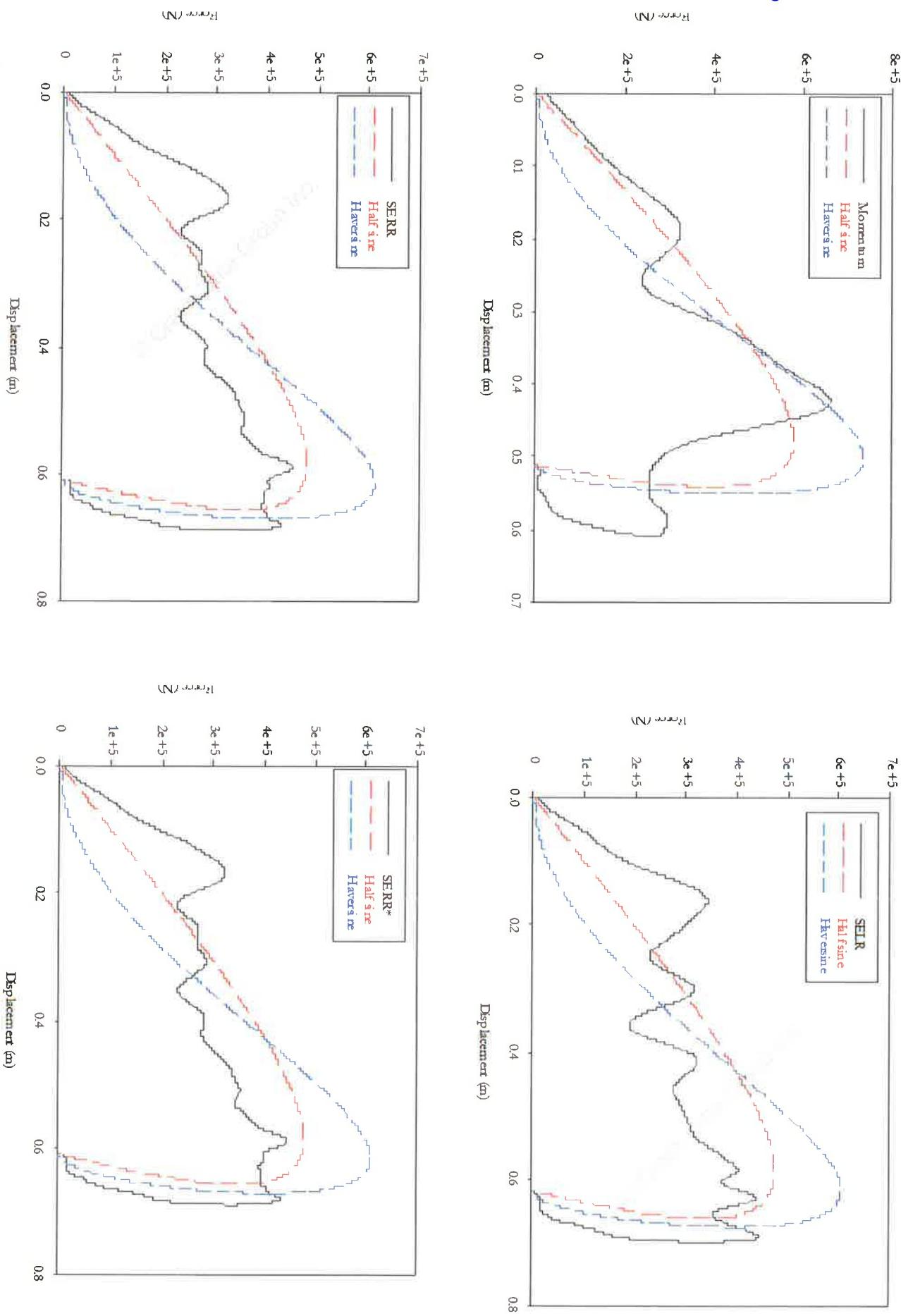
Figure 4. Force-displacement histories for the momentum (A), left rear crossmember accelerometer (B), right rear crossmember accelerometer (C) and redundant right rear crossmember accelerometer (D) solutions.

tests provides yet another method for evaluating this form of collision test data. The forms of the equations are best compared with the work of Varat and Husher [2003] and with the authors' prior work [Singh and Perry, 2007]. For both the half sine and haversine collision pulse, the solution for the pulse amplitude and the second constant of integration differ. This is an expected finding in that the desired boundary and parameter conditions in the two formulations differ. An analytical comparison regarding the circular frequency and the crush depth between the two formulations is difficult to make in that the former variable is defined a priori in the prior model formulation while the latter parameter is defined a priori in the subject formulation. For the example evaluated, the use of the desired boundary velocity and displacement constraints resulted in a predicted collision duration that was shorter than that which was measured and a circular frequency that was greater than that which would have been calculated for a sine based model in which the collision duration was taken as a known input in the formulation. It remains to be seen if this finding holds true for a broader sampling of vehicles. The shorter predicted collision duration did result in the expected finding of greater amplitudes for each model when compared with the prior formulation. This result was expected in that for a given change in velocity for a given pulse shape, shortening of the base of the pulse would necessarily result in a corresponding increasing of the magnitude of the pulse.

Another interesting finding from the subject study is the form of the equations governing the predicted kinematic and force-displacement response. Unlike the prior formulation in which the crush depth was allowed to reach its value based upon other model inputs, treating the crush depth as a requisite input condition resulted in the kinematic and force-displacement responses being undefined for the case of purely elastic unloading. This condition is achieved when the crush depth takes a value of zero and has a corresponding coefficient of restitution value of unity. This is a theoretical limitation of the subject formulation but for the modeling of actual data from the subject tests, is not one that is reasonably applicable (i.e. the vehicles tested under the subject conditions do not exhibit purely elastic unloading).

The force-deflection responses exhibited in the subject formulation for the example evaluated produced higher peak force values and resulted in correct matching of the crush depth. The peak deflection, however, was underestimated as is evidenced by an examination of Figure 4. The prior formulation, in contrast, predicted lower peak force values (when compared to the subject formulation), greater peak displacement values and greater crush depth values. These findings, again, are explainable as the direct result of the boundary conditions and parameters used for developing each of the formulations. These findings would be expected to hold regardless of the test under consideration. The predicted force-crush response for both model formulations follows that of the prior formulation. That being, both formulations are generally non-linear with a dependency on the coefficient of restitution. It is only when the coefficient of restitution has a constant value do the subject equations predict a constant linear relationship between force and crush. Conversely, the assumption of linearity between force and crush depth only allows for the consistent usage of the subject form of the collision pulse models when the coefficient of restitution is constant over the range under consideration. Based upon the findings of the subject study and upon the prior

work, it would appear that model formulations based on separate asymmetric loading and unloading regions would be worthy of consideration such that both the peak dynamic displacement and the resultant crush depth could be matched. Further work in regards to the this potential method is underway by the authors as well as work regarding the use of optimization based general power sine models for modeling the subject collision pulses from the subject form of collision test.

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C

Dynamic Accuracy of Powertrain Control Module (PCM) Event Data Recorders During ABS Braking

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Abstract

The primary purpose of this paper is to evaluate the accuracy of speed data recorded in the Ford PCM under dynamic maximum ABS braking conditions. The authors drove a rear wheel drive 2005 Crown Victoria Police Interceptor starting at 5 different initial speeds from 48 to 113 kph (30 to 70 mph), making 6 runs at each speed, then braking as quickly as possible to a stop and turning the key off at the end of the run. The authors collected PCM EDR data after each run, which recorded the prior 25 seconds of speed and brake light switch on/off at 0.2 second intervals. The vehicle was also instrumented with a GPS based Racelogic VBOX III that measured vehicle speed and brake light switch voltage at 100 times a second whenever it was activated. The PCM brake switch on/off signal was used to synchronize the data to the VBOX brake light voltage signal so the readings could be compared at the same points in time. The authors compared the readings and calculated average and maximum differences. The authors then described how this data can be used to better estimate speed at impact from the last data point recorded during braking from a PCM EDR record.

Introduction

Prior papers have assessed the accuracy of pre crash speed data in automotive event data recorders such as General Motors Sensing and Diagnostic Modules (SDM's) during steady state conditions. Chidester (1999) stated the accuracy was 4%. Lawrence (2003) tested vehicles using a 5th wheel and found SDM speed to be over reported by 1.5 kph at low speeds and under reported by 3.7 kph at high speeds up to 150 kph. Niehoff (2005)

reported on 28 crash tests from 40 to 64 kph and determined the average error in pre-impact speed was 1.1% with a maximum error of 3.7%. Reust (2006) (reference #4) reported accuracy for GM SDM EDR's under maximum ABS braking dynamic conditions to be within 8 to 18% over 30 mph. Reust (2006) (reference #5) also reported accuracy of commercial truck EDR's under heavy braking to be within xx%. To the author's knowledge, the dynamic braking accuracy of pre crash speed data in Ford Powertrain Control Modules has not yet been reported.

Ford began installing an event data recorder function in the Powertrain Control Modules of 2003 and later vehicles equipped with Electronic Throttle Controls on gasoline engines. Like GM SDM speed data, the source of speed data is the transmission output shaft speed sensor, and the speed is calculated in the Powertrain Control Module. The key differences with possible effects on dynamic speed data accuracy calculations include:

1. Ford data is reported every 0.2 seconds (vs. every 1 second on GM SDM's to date).

2.Ford speed data is reported to a resolution of 0.01 mph (vs. rounded to nearest 1 mph for GM).

3.Ford data is continuously recorded in real time to an EEPROM in the PCM and locked by a deployment event (versus GM sending the data on a class 2 serial bus from the PCM to the SDM asynchrously, buffering it in SDM RAM, then writing to an EEPROM only in the event of a nondeploy or deployment event).

Methods

A rear wheel drive 2005 Crown Victoria Police Interceptor vehicle was instrumented with a Racelogic VBOX III set to record vehicle speed from GPS location and brake light voltage (among other things). It also recorded the number of data channels reporting, which became significant later when the brake light voltage signal recording malfunctioned, but the number of channels reporting allowed a secondary indication of brake light application.

The test procedure consisted of turning the Vbox recording system on, accelerating the vehicle to a known steady state speed, taking the foot off the accelerator rapidly and depressing the brake pedal as quickly and as hard as humanly possible, until the vehicle came to a complete stop. The VBOX recording was then stopped and the Ford PCM event data recorder memory was read out, showing the last 25 seconds of speed and brake activity.

Six runs were conducted at each chosen speed of 48.3 kph (30mph), 64.4 kph (40 mph), 80.5 kph (50 mph), 96.6 kph (60 mph), and 112.7 kph (70 mph).

The VBOX data was then synchronized with the PCM data by using the brake light voltage signal. Because the VOBX reported at 0.01 second intervals and the PCM reported at 0.2 second intervals, the VBOX point 0.1 seconds prior to the last point with no voltage applied was matched to the last PCM point with no brake light on. On average this should match, but the authors acknowledge there is an uncertainty of +/- 0.1 seconds in the synchronization due to the PCM sampling rate not being the same as the VBOX. After the synchronization was established, the prior 20 VBOX speed data points were averaged prior to comparing it with the PCM speed data.

Results

Shown in the figures, a typical single data run showing deceleration from a starting speed of 112.7 kph (70 mph) to a complete stop. The Ford PCM data and the Racelogic VBOX III data are both displayed versus time, and the VBOX-PCM difference in mph is also displayed near the bottom of the graph.

Because of variations in the starting speeds and braking rates and times, plotting data versus time from first brake application did not align the data sets. The authors found that displaying the event using an X axis of VBOX speed (plotted in reverse order) allowed the event to be viewed as if time were progressing from left to right, but allowed multiple data sets to be compared more easily. The same information from the single run from Figure 1 is plotted below in Figure 2 with the PCM speed as the Y axis and the VBOX speed as the X axis. A reference line has been added

where the PCM speed would equal the VBOX speed, such that the differences between the two are easier to view. The difference is also plotted as a separate line near the bottom of the graph.
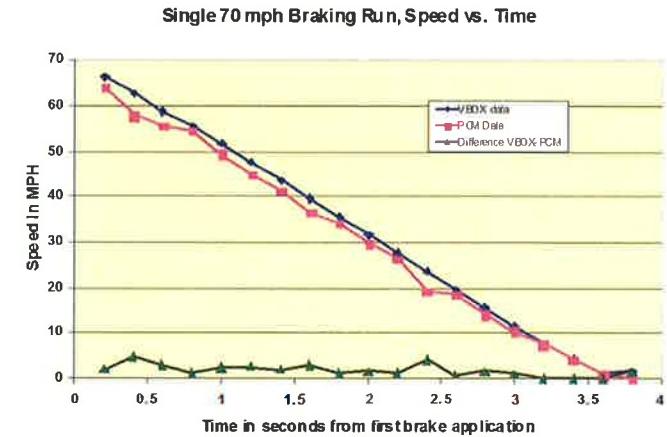
Figure 1
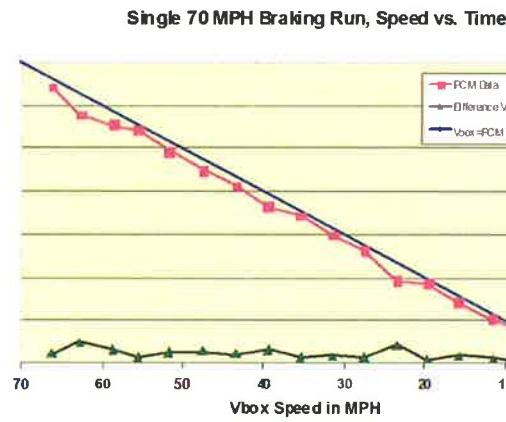
Figure 2

Note the dip in PCM speed shortly after brake application. This dip was observed on most of the individual data run plots.

Data points from all 30 runs can be plotted on the same graph to show the overall results. See Figure 3 below.
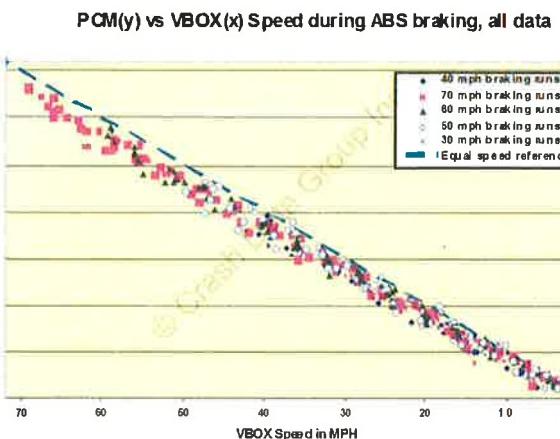
Figure 3

Because of the 70 mph scale required to see all the data, it can be difficult to gauge the exact size of the difference between the PCM data and the Vbox data. The authors therefore plotted the differences alone without the absolutes, allowing the scale to be expanded in Figure 4 to allow viewing the difference data in greater detail.

VBOX-PCM difference in MPH during ABS braking, all data
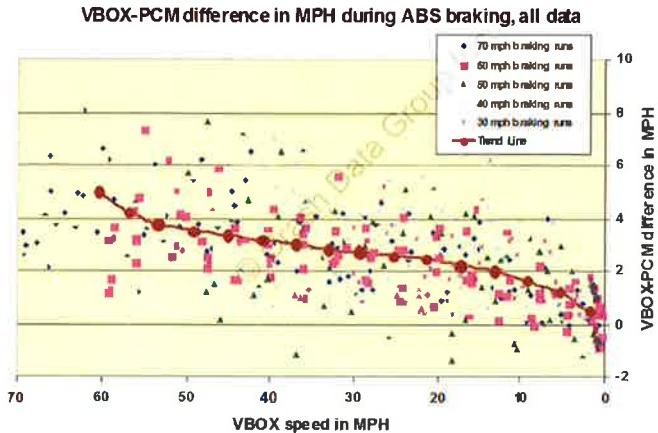
Figure 4

The data shows that the maximum difference observed was 8mph at 62 mph speed, but the average difference observed varied with the test speed. At 65 mph the difference averaged 5 mph. The average difference was less at lower speeds, averaging approximately 2.8 mph at 30 mph.

VBOX-PCM difference in % during ABS braking, all data
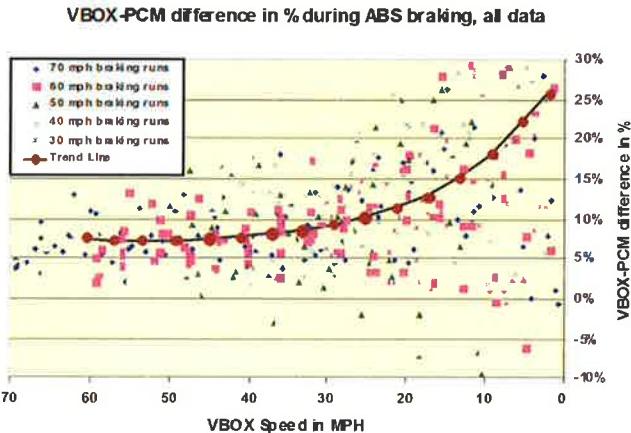
Figure 5

When the same data is viewed in percentage terms in Figure 5, the maximum difference observed over 50 mph was 13%. The average difference is about 7.5% at 65 mph and while the absolute difference is less at lower speeds, the percentage difference gradually increases at lower speeds as the denominator in the percentage equation gets smaller. At very low speeds the PCM reported some wheel speeds as zero indicating the wheels had locked while the VBOX still reported some slight movement, resulting in 100% error being reported. The graph was deliberately cut off above 30% and does not show some points below 8mph to allow the scale to show better resolution at higher vehicle speeds.

Returning to the dip in PCM reported speed observed just after initial brake application, the authors averaged the six runs at each initial starting speed together and plotted the results of the first 4 points for each speed run in Figure 6.

Vbox - PCM Average Difference in MPH during ABS Braking
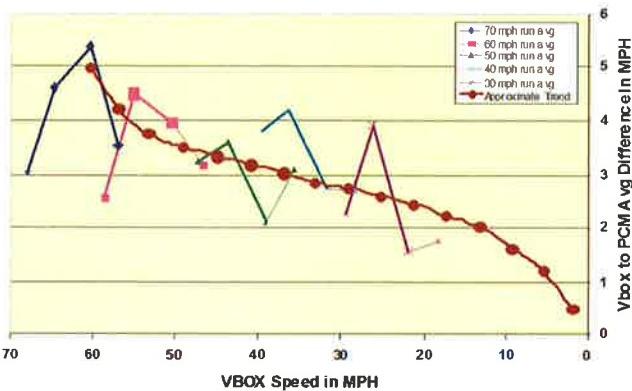
Figure 6

As the ABS brakes are initially engaged, the average difference for each initial test speed rises above the trend line as shown in the bolded first few data points for each starting speed series.

Discussion

In figure 4 there are a small number of points below the zero line where the PCM reported speed was below the VBOX reported speed. During a normal braking situation on hard pavement where there is good traction, the authors would never expect the wheel speed to be greater than the ground travel speed. The authors acknowledged the synchronization can have a +/- 0.1 second error associated with it, and under hard braking this can result in a +/- 2 mph effect on reported speed. The negative differences are most likely a result of synchronization variations.

The purpose in developing this data is to better estimate the actual speed at impact from the last PCM EDR data point recorded before impact. In a steady state vehicle speed condition the last PCM data point recorded should equal the speed at impact. During dynamic braking conditions, the PCM will under-report vehicle speed due to the ABS system slowing the wheels which also slows the transmission output shaft speed sensor used to calculate PCM vehicle speed. The range of possible under-reporting must be added to the last data point recorded to better estimate the speed at impact. For example, at 65 mph, if the brakes had just been engaged such that the "dip" in the PCM speed may be possible, an adjustment range of approximately +8/+2 mph may be appropriate. At 30 mph, if the braking had been taking place for more than a half second such that the "dip" in the PCM speed curve was unlikely to be present, an adjustment range of approximately +4.5/+1.0 may be appropriate.

In addition to the dynamic braking effect, the last data point recorded in the PCM can vary in time from the moment of impact to 0.2 seconds prior to impact. If the last point recorded was 0.2 seconds prior to impact, then under hard braking, an additional 4 mph of vehicle speed could be scrubbed off prior to impact. This adjustment range would be approximately +0/-4 mph on normal dry road surfaces. This is shown conceptually in Figure 8.

Estimating Speed at Impact
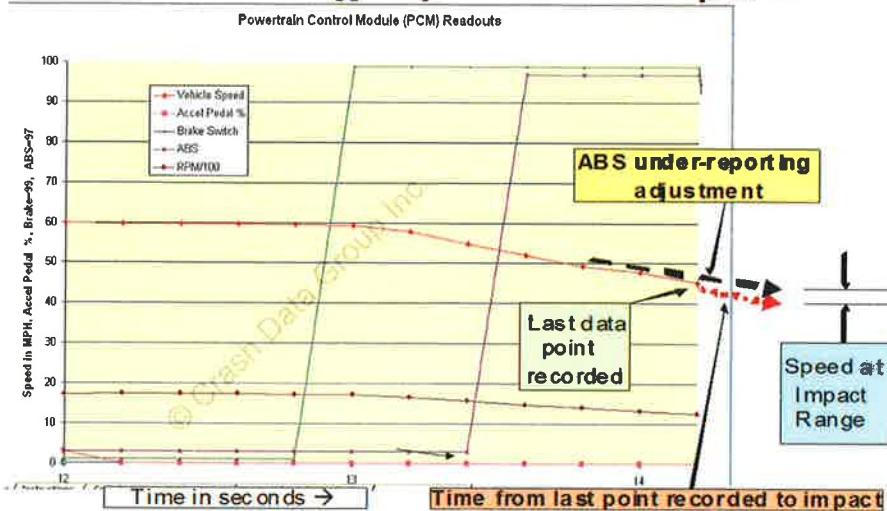
Figure 7

The ABS braking effect is partially offset by the uncertainty in time of the last data point. The net effect is the sum of the two. For

example, at 65 mph, the ABS range of +8/+2 could be combined with the timing uncertainty of +0/-4 for a net of +8/-2.

Conclusions
The Ford PCM may underreport vehicle speed by up to a maximum of 8mph during ABS braking at highway speeds. The average underreporting is approximately 5 mph at 65 mph, and the average underreporting is less at lower speeds as depicted in Figure 4.

Allowances for possible underreporting must be considered when estimating speed at impact from the last data point recorded prior to impact during ABS braking. Allowances for possible time delays between the last data point recorded and the moment of impact must also be considered.

Acknowledgments
The authors wish to acknowledge Brad Muir for arranging access to the Ontario Police College Test Track for a portion of the testing, and for the use of an Ontario Provincial Police test vehicle. Thanks to James Morgan for initially synchronizing Vbox and PCM data.

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Definitions, Acronyms, Abbreviations
ABS – Anti-Lock Braking System
EDR – Event Data Recorder
EEPROM – Electrically Erasable Programmable Read Only Memory
GPS – Global Positioning System
PCM – Powertrain Control Module (Ford term)
RAM – Random Access Memory
RCM – Restraint Control Module (Ford term)
SDM – Sensing and Diagnostic Module (GM term)

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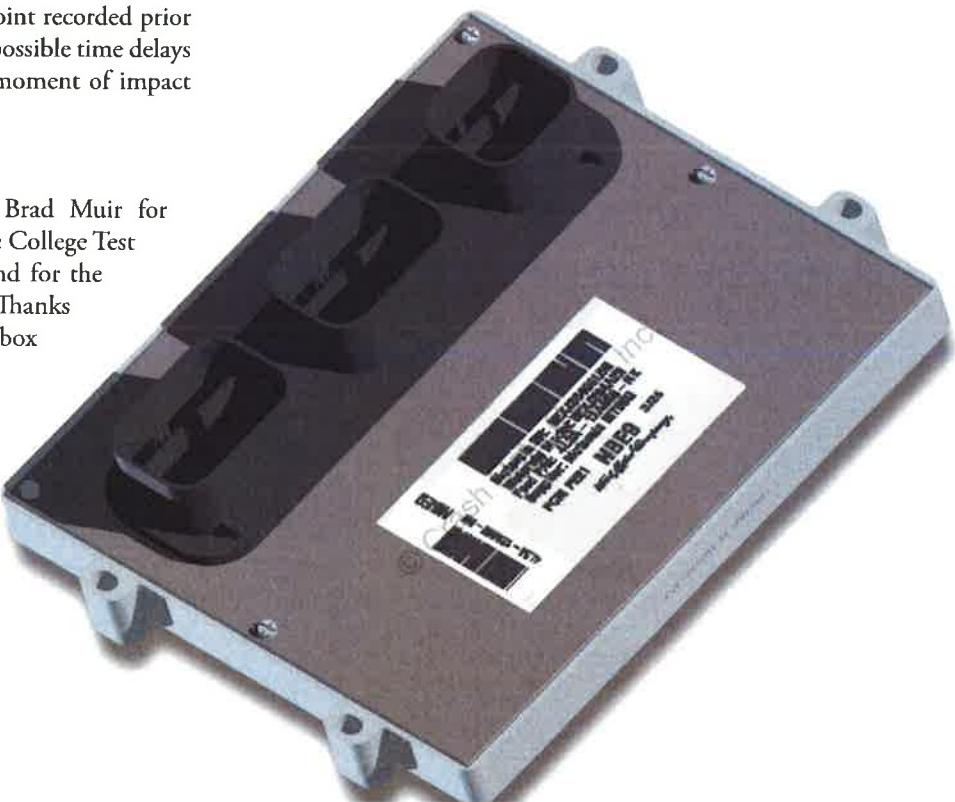
The Accuracy of Speed Recorded by a Ford PCM and the Effects of Brake, Yaw and Other Factors

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Abstract
The current trend in accident reconstruction is to make use of recorded electronic event data. The accuracy of the speed recorded by a SDM (Sensing and Diagnostic Module) in passenger vehicles and an ECM (Electronic Control Module) in commercial vehicles has been tested and published by researchers. The accuracy of the speed recorded by a PCM (Power Control Module) in Ford vehicles during dynamic conditions has not previously been published. Well documented tests were conducted with instrumented vehicles to enable a comparison of a calibrated speed to the PCM recorded speed. The purpose of this paper is to provide information on the accuracy of the speed during normal operating conditions, heavy acceleration, cornering, maximum brake application and during critical speed yaw events. The PCM-reported speed data is generated from the vehicle speed sensor and reports the speed proportional the rotation of the vehicles drive wheels.

Figure 1   2005 Ford Crown Victoria, cvspeed23
Steady Speed ~60mph
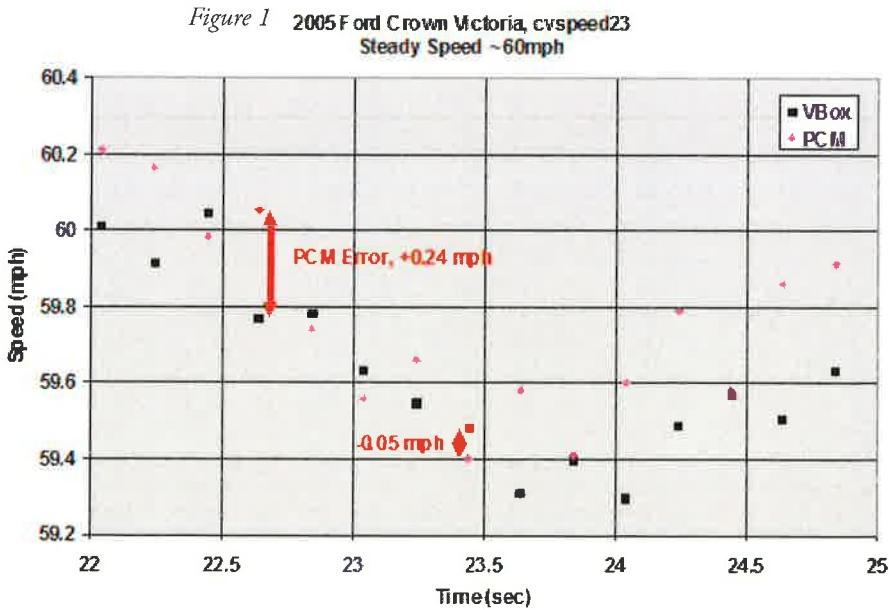
Introduction
Late model Ford vehicles incorporate an event data recorder in the Power Control Module (PCM) and can be downloaded using the Bosch CDR 3.0 software and cables. The PCM records data at 5 samples per second and with the 3.0 software provides speed in units of miles per hour and in 0.1 mile per hour increments.

2007 Ford F-150, f-150-5
Steady Speed ~ 60 mph

Figure 2

Results of Steady Speed Tests

+0.60
- 0.83

Figure 3

2005 Ford Crown Victoria, cvspeed11
Low Level Acceleration

+0.37
- 0.15
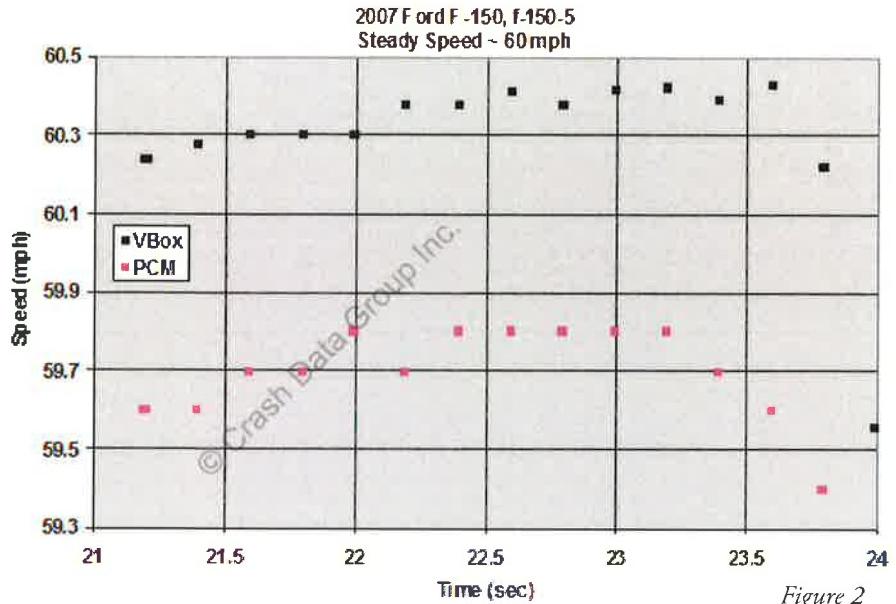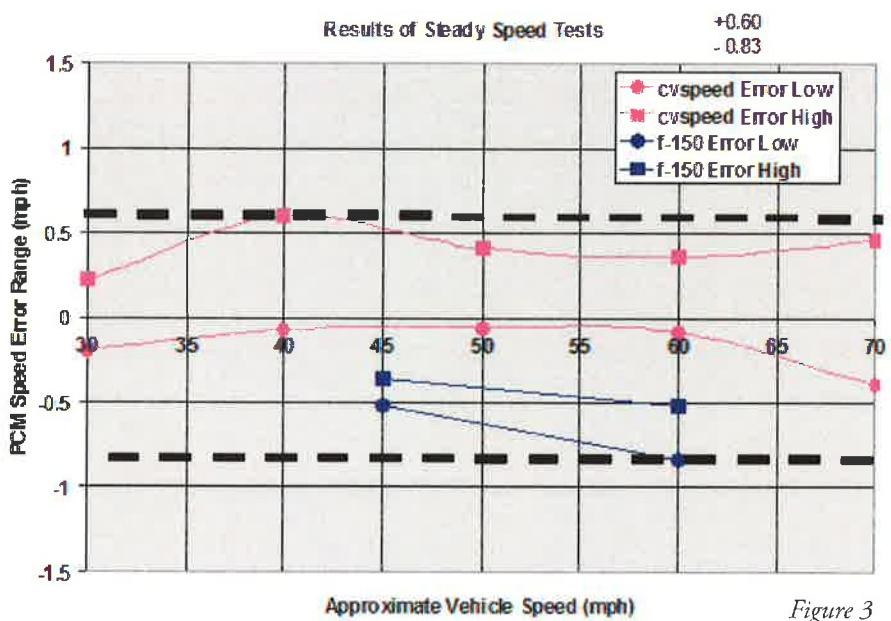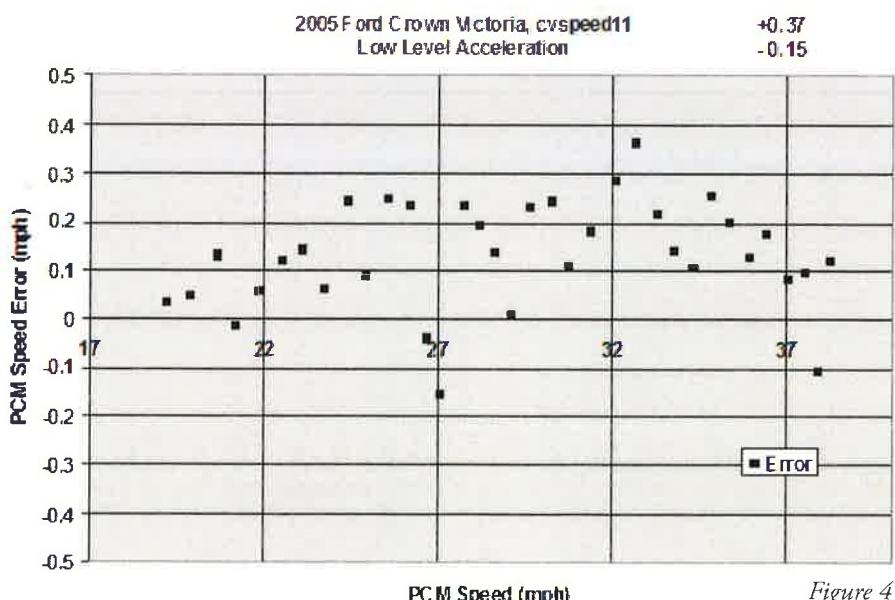
Figure 4

Other information recorded by the PCM includes, engine RPM, throttle percent, brake application, antilock brake activation and traction control activation. The vehicles used for this study were a 2005 Ford Crown Victoria Police Interceptor and a 2007 Ford F-150. The tires of the vehicles were the original equipment size and were inflated to their recommended pressures.

The current trend in accident reconstruction is to make use of the available electronic event data.   The data can make a significant contribution to the engineering reconstruction of a vehicle accident.   In some cases, the PCM data can provide information   that   traditional   accident reconstruction methods cannot.

Instrumentation
The calibrated vehicle speed was recorded using a Racelogic VBOX III GPS system. The speed recorded by the VBOX system has an accuracy of 0.063 mph averaged over four samples. The VBOX was also wired and programmed to record brake pedal contact, brake light switch power, accelerator pedal position and throttle position data. Contact of the brake pedal was recorded by placing a tape switch on the surface of the brake pedal. Accelerator pedal position and throttle position sensor information was obtained by placing wire taps onto the leads of the vehicle's position sensors. The Racelogic (IMU) Inertial Measurement Unit was used to measure roll, pitch and yaw rates and x, y and z acceleration. The VBOX III system records data at 100 samples per second.

Test Duration Consideration
The VBOX system is able to record data continuously for long durations of time. The PCM for the test vehicles were known to provide a 25 second loop of data. Consideration was given to the time length of each test and the possibility of having PCM data overwritten during a test lasting longer than 25 seconds. For each tests, after the vehicle was brought to a stop, the ignition was turned off immediately to prevent overwriting of the PCM test data.

Data Reduction
Each test produced two data sets, the VBOX instrumentation data at a rate of 100 Hz and the PCM data at a rate of 5 HZ. The two data sets were synchronized initially by matching the

2007 Ford F-150, f-150-2
Low Level Acceleration   - 0.17
                                     - 0.67

Figure 5

Results of Low Level Acceleration Tests   +0.37
                                                - 0.67

Figure 6

2005 Ford Crown Victoria, cvspeed26   +1.18
Maximum Acceleration   - 0.23
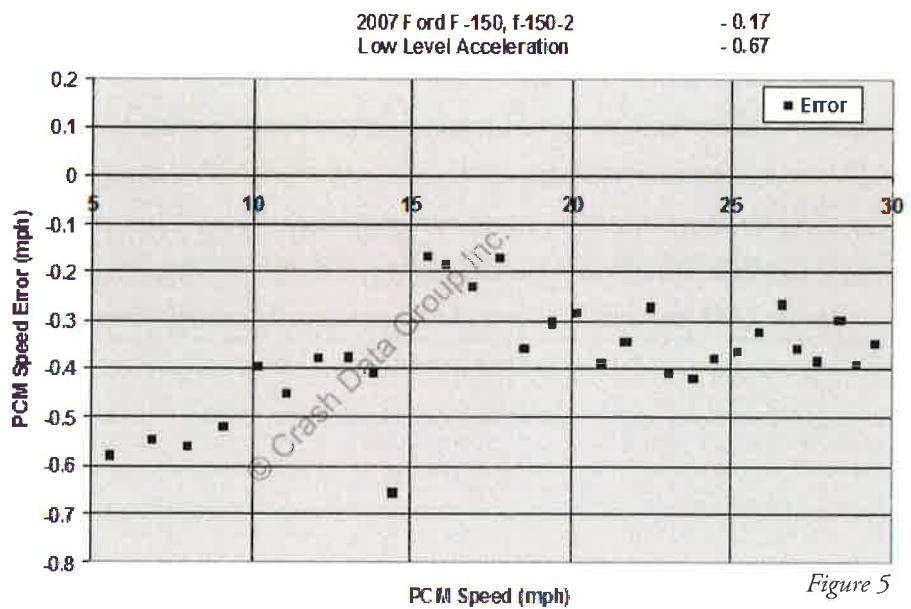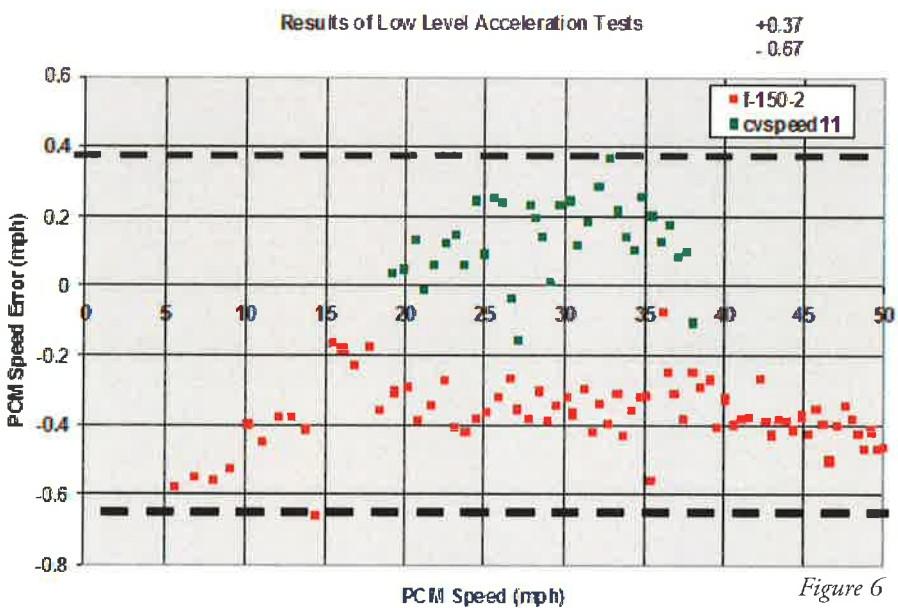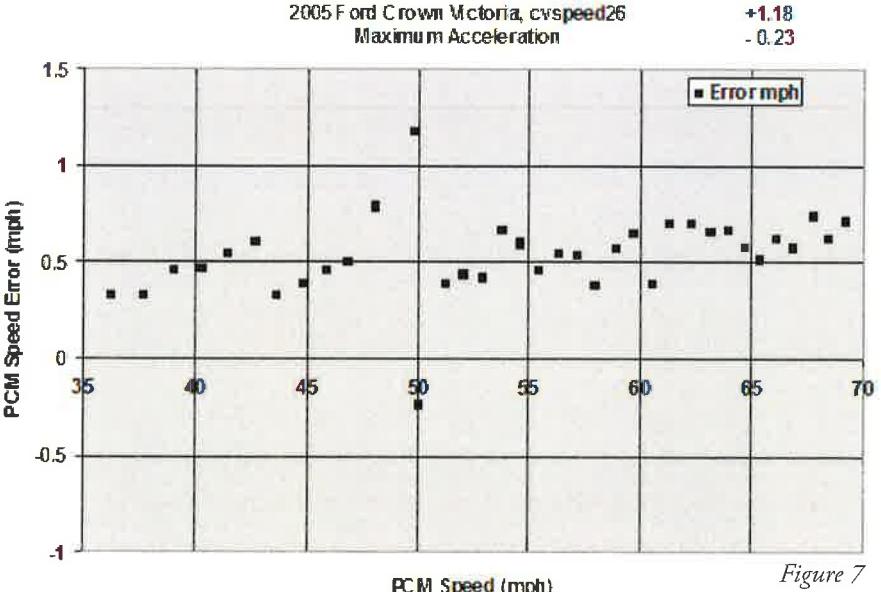
Figure 7

brake signal data and then fine-tuned using throttle data. The speed data from the VBOX system was used as the calibrated speed for each test. After the data was synchronized then each speed point could be analyzed in terms of a numerical difference or a percentage difference.

Speed Accuracy During Steady Speeds
During these tests, the vehicle was accelerated to a target speed and then maintained for a period of time. Each set of test data was evaluated to determine the difference between the calibrated speed (VBOX) and the PCM-reported speed. Examples of the speed difference during a relatively steady speed of 60 mph are shown in (Figure 1) for the Crown Victoria and in (Figure 2) for the F-150. The results of the combined tests for speeds between 30 to 70 mph are shown in (Figure 3). This shows an overall accuracy during steady speeds of +0.60 to -0.83 mph, meaning that the PCM-reported speed is over-reported by as much as 0.60 mph and under-reported by as much as 0.83 mph. Individually it was observed that the Crown Victoria error ranged from +0.60 to -0.40 mph and that the F-150 error ranged from -0.30 to -0.83 mph.

Speed Accuracy During Low Level Acceleration
During these tests, the vehicle was accelerated in a slow manner. Each set of test data was evaluated to determine the difference between the calibrated speed (VBOX) and the PCM- reported speed. Examples of the speed difference during low level acceleration are shown in (Figure 4) for the Crown Victoria and in (Figure 5) for the F-150. The result of the combined tests for a speed range between 5 to 50 mph is shown in (Figure 6). This shows an overall accuracy during low level acceleration of +0.37 to -0.67 mph.

Speed Accuracy During Maximum Acceleration
During these tests, the vehicle was rapidly accelerated. Each set of test data was evaluated to determine the difference between the calibrated speed (VBOX) and the PCM- reported speed. Examples of the speed difference during maximum acceleration are shown in (Figure 7) for the Crown Victoria and in (Figure 8) for the F-150. The data for the Crown Victoria showed two individual

higher speed errors (+1.2) at 35 and 50 mph. Further review of the data indicated that gear shifts had taken place at these two points. Result of the combined tests for a speed range between 5 to 70 mph is shown in (Figure 9) and shows an overall accuracy of +0.79 to -0.63 when the gear shifts are excluded.

Speed Accuracy During Yaw Events
Yaw testing of the vehicles was conducted in two different ways, one with steering only and the other with steering and braking combined. The yaw tests when only steering was used showed the PCM-reported speed was underreported by approximately 0.02 to 2.9 percent (Figure 10). The yaw tests involving both steering and braking showed the PCM-reported speed was underreported by approximately 0.11 to 5.15 percent (Figure 11). The graphs also include later acceleration and yaw rate.

Speed Accuracy During ABS Brake Events
Data from the PCM download will provide information indicating when the ABS is "Active" and "Not Active". The "Active" reading occurs when the ABS system is _activated_. In the tests that were conducted it was observed that the "Active" reading remained on constantly during a maximum effort brake event. Testing with the Crown Victoria showed that the PCM-reported speed is underreported by approximately 0.69 to 14.32 percent during an ABS brake event at speeds above 20 mph (Figure 12). Testing with the F-150 showed that the PCM-reported speed is underreported by approximately 0.48 to 12.68 percent during an ABS brake event at speeds above 20 mph (Figure 13).

The data from the PCM download also indicates when the brake switch is "ON" indication application of the brake pedal. The testing result showed that during a maximum brake effort that the ABS system is not activated immediately upon brake application but comes on approximately 0.4 to 0.6 seconds after the "ON" signal

Conclusion
Based on the tests conducted for this paper, the accuracy of the PCM-reported speed during low and maximum acceleration and during steady speeds is approximately ± 0.8 mile per hour. The tests did show that the

Figure 8

Figure 9

Figure 10

The World According to G.A.R.P.*

(*Generally Advocated Reconstruction Propaganda)

Lessons I Learned From
Accident Reconstruction Software Marketers
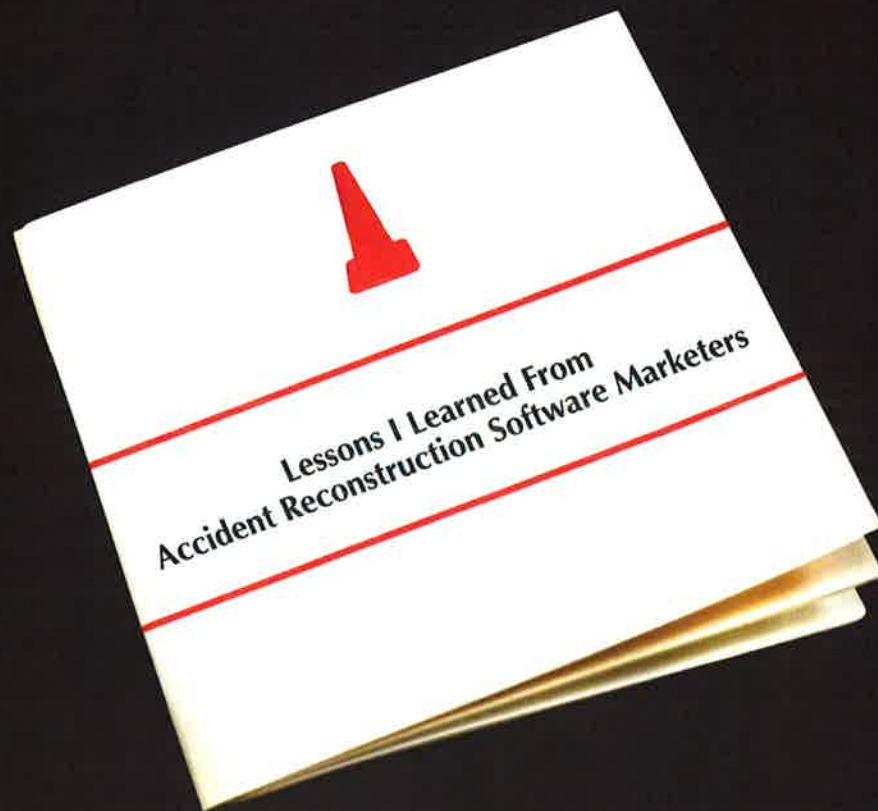
1. The world is flat.

2. Cars only crash on flat, straight roads.

3. Roads are made of ice. When cars crash they glide gracefully and spin like a figure skater.

4. Highway engineers make roads the same size - universally. (There is never a need to measure both sides.)

5. Accidents only happen on sunny days.

6. When cars slide on their roof, hood, trunk, or side, they leave tire marks.

7. Fences and signs are made of space-age material.
This allows vehicles to pass through them without causing damage.

8. An eight year old child can be an accident reconstructionist - given the right software, of course!

Now, Is this your world?
Really....

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Event Timeline

Problem: Most animation products don't let you easily see the "big picture".

Solution: MapScenes Capture gives you instant visual feedback of your animation by displaying event timelines for all your animated objects and cameras.
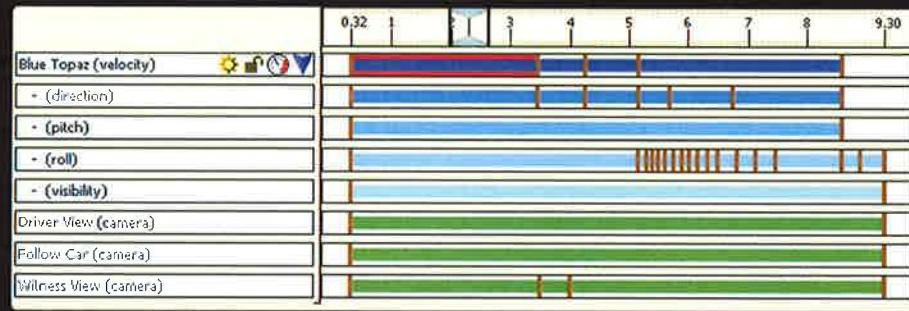
Advanced Symbol Control

Problem: Precise movement of objects in animations can be difficult and frustrating. Most symbols need adjustment of the base point (X, Y, Z) and direction.

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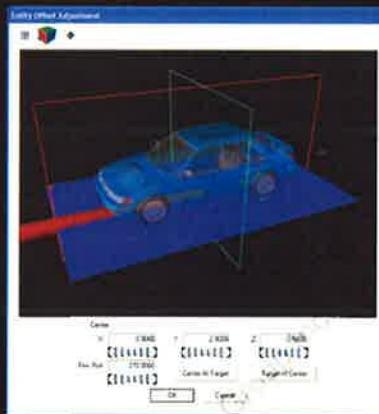
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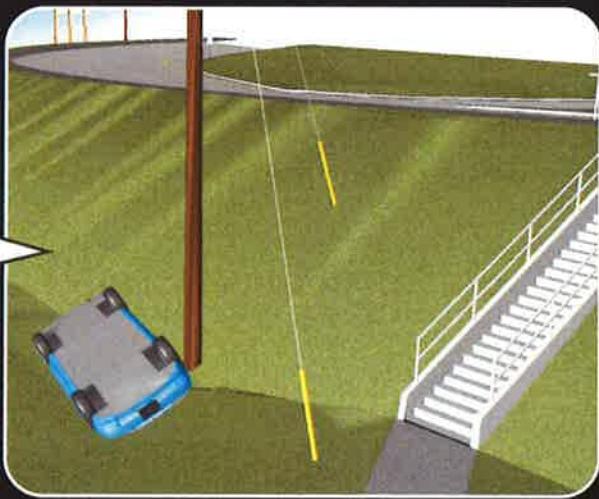
To view animation designed for the real world go to www.mapscenes.com/capture

Capture

2005 Ford Crown Victoria, vic2   0.11% to
Yaw with Brake   5.15%

Figure 11

2005 Ford Crown Victoria, cvspeed26   0.69%
ABS Brake, 0.882g   14.32%
Brake Application at 25.76 sec

Figure 12

2007 Ford F-150, f-150-3   0.48%
Brake Application at 20.73 sec, 0.876g   12.68%

Figure 13

Crown Victoria tended to slightly over report the speed and the F-150 tended to slightly underreport the speed. During maximum acceleration when a gear shift took place with an automatic transmission the speed was observed to be over-reported by approximately 1.25 miles per hour for one data sample during the shift.

During maximum brake application of a vehicle with an ABS system, the PCM-reported speed is underreported by approximately 0.5 to 14.3 percent at PCM-reported speeds of 20 miles per hour and higher

When a vehicle is in a critical speed yaw the PCM-reported speed will be underreported by approximately 0.02 to 2.9 % when only steering has been used and will be underreport by approximately 0.11 to 5.2 % when both steering and braking have been used.

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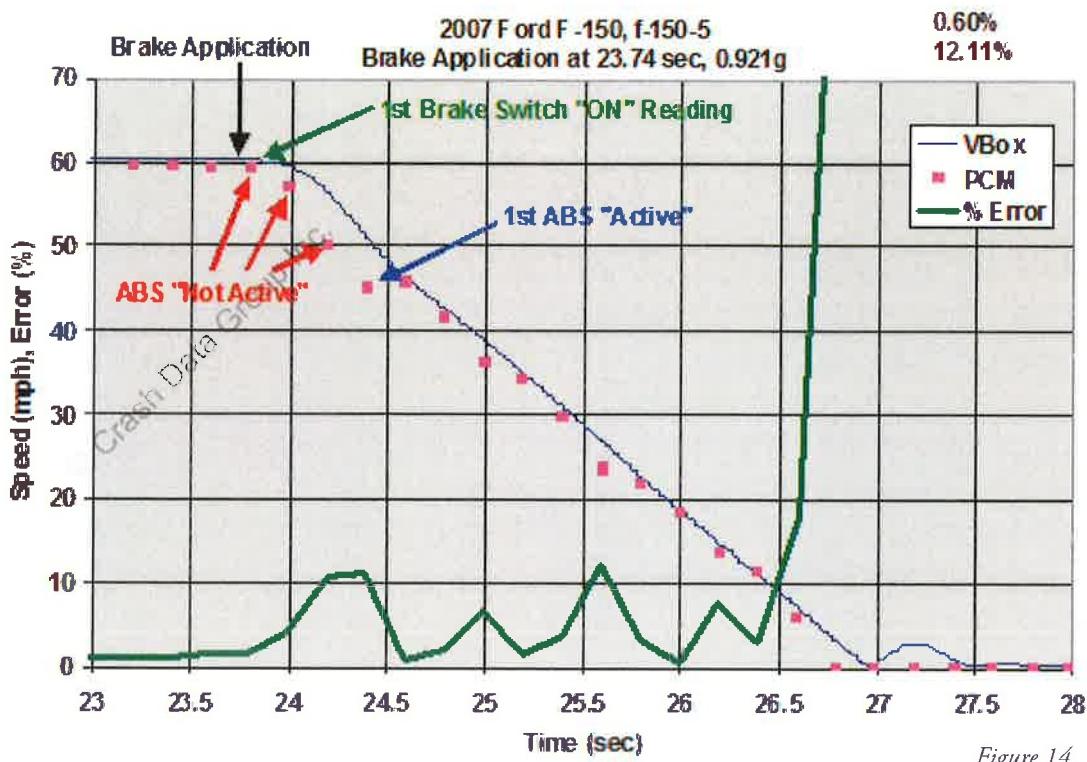
Figure 14

C

The DBD Crush Deformation Jig

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See class schedule for "Speed Determination from Crush Analysis" class.

Book Reviews

Joseph E. Badger

About the reviewer:

Joseph E. Badger, retired state police officer and internationally known crash reconstructionist, has reviewed and evaluated accident reconstruction computer programs and books for nearly two decades. Author of the book Trailer Underride: Conspicuity, Human Factors and Rear Bumpers (IPTM, 1998), Mr. Badger has written over one hundred articles published in such periodicals as the Accident Reconstruction Journal, Accident Investigation Quarterly, Law & Order magazine, and Police & Security News.

Anatomy of the Collision: Third Edition or *The Collected Works of George Bonnett*

ANATOMY OF THE COLLISION

ENERGY, MOMENTUM, RESTITUTION AND THE RECONSTRUCTIONIST

1st Edition – revised and expanded

George M. Bonnett, JD
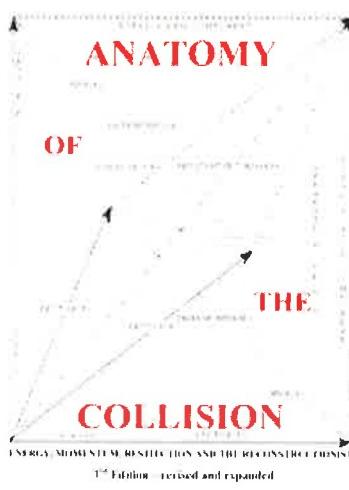
Back in a previous millennium (1999), the Institute of Police Technology&Management (IPTM) published *Anatomy of the Collision* by George Bonnett. It contained 227 pages and covered topics ranging from Momentum, Understanding Delta V from Damage, Kinetic Friction, Airborne Drag Factor, Uniform Circular Motion and Inertia, Deceleration in a Yaw, and Calculating Principal Direction of Force Angles.

The first 94 pages analyzed damage, restitution and Delta V of eight major collisions with 44 variants involving momentum and energy. The next 20 pages made up a workbook that took you through those eight collisions with "Variations on a Theme."

Anatomy of the Collision resulted from the collection of hard lessons learned in creating REC-TEC.

Because of the difficult issues that had to be solved or overcome in perfecting the program, Bonnett wrote a number of articles designed to make life easier for those in the accident reconstruction field.

Anatomy of the Collision was not a course textbook that showed how to work specific collisions. Rather, Bonnett described various approaches to problems and discussed methods of attack that help you understand the issues involved. It prepared you to solve similar problems and defend your approach to the solutions as well as the methodologies employed in arriving at them.

After IPTM published the book, Bonnett couldn't leave well enough alone. He had to make his book "New and Improved" by adding more chapters on such topics as stiffness coefficients, the problem with turns and constants and what lies beyond Crash3.

That revised book became *Anatomy of the Collision, Second Edition.*

And he still wasn't finished.

The new book, *Anatomy of the Collision – Third Edition*, retains its original material, including the workbook portion, plus three new chapters.

Here are the chapter titles, with my description of the contents of each:

Conservation of Momentum
This section discusses restitution, line of impact, Delta V, viscoelastic waves and other topics obscurely related to momentum.

Vector Momentum Analysis
This is linear momentum in reverse. If we know how fast and at

what angles the objects entered collision, what are the departing possibilities.

Understanding Delta V from Damage*

This is a basic overview of the Damage Analysis phase of Crash3, including the proof for non-equidistant "C" measurements. In this chapter, Bonnett discusses some of Crash3's assumptions and weaknesses and explains his rationale for his concerns about a program originally designed as a research device, not an accident reconstruction tool.

Beyond Crash3 - Delta V from Damage*

This section looks at where Crash3 is, where it may go, and why this path is not only relevant, but also necessary. It also shows how similar this new path is to what is now an acceptable extension of Crash3 while it deals with some of the inherent problems with the Crash3 software and its successors.

Effect of Grade on Kinetic Friction

This is a look at an improved method for dealing with the effect of grade on road friction.

The Airborne Drag Factor - Flying at Zero Altitude

This chapter studies the effects of aerodynamics on the stopping distances of vehicles.

Secondary Slap - Two Collisions or One?

This section offers proof that the secondary slap does not prevent the use of COLM, it may make the job easier.

Measuring Linear Momentum Angles

This piece attempts to use reason and logic to explain the correct approach to measuring departure angles.

Simultaneous Linear and Angular Deceleration

A truly delightful read dealing with rotation and linear motion at nominal and theoretical levels that will keep the reader captivated for nanoseconds at a time

Uniform Circular Motion and Inertia

Delta V and maximum rate changes of direction team up for another thrilling tale of motion.

Deceleration in a Yaw

A textual and graphical display showing the problems involved with multi-tasking.

Collision Times Four

Here we have an in-depth study of four basic collisions and their differences and similarities including a look at both energy and momentum.

Calculating PDOF Angles

Vector addition and subtraction is employed to discover the truth about PDOF and Delta V.

Stiffness Coefficients - Energy and Damage

Just when you get comfortable with Crash3 and stiffness coefficients, this comes along to make things very different. How do we deal with Impactors?

The Problem with Turns

This chapter really is not about turning as in "Mildred, turn left at the next intersection." Or, "Billy Bob, you done made an illegal U-turn." The topic deals with swerving or turning away when coming upon a stopped or slower-moving vehicle (or some object on the roadway), a situation requiring a lane change.

Inline Collisions – A Straight Forward Approach

Here we study of the inline collision using energy and momentum.

The Constant Problem

This is not about a continuous predicament, but rather the problem with that dreaded "given" in an equation called a "constant." The most common constant among accident reconstructionists is the number 30 found in the slide-to-stop formula. It is one of those tricky items developed to convert feet per second to miles per hour AND to handle that feet-per-second-per-second value fondly referred to as the acceleration due to gravity. Unfortunately, it doesn't appear in any "real" physics book.

The following new chapters are in the Third Edition:

Pedestrian Vaults – Humans Going Ballistic*

If you look long enough in the literature, you are apt to find at least 85 different equations to use when a pedestrian gets struck and flies through the air with the greatest of ease, or a motorcycle rider gets launched after colliding with the side of a car.

If you know (or assume a range for) the launch angle, surface friction and throw distance, solving for the pedestrian's vault speed is simply a matter of doing the math. Bonnett says you do not need 85 different formulas, as four basic equations found in any physics book will work just fine. His book demonstrates how by leading the reader through a sample problem.

Basic Photogrammetry*

This chapter shows how to use photogrammetry to obtain measurements from photographs using a technique called numerical rectification.

Momentum: Myths and Misconceptions*

Here, Mr. Bonnett takes you through some common mistaken beliefs such as vehicles must always reach a common velocity or that they must exit maximum engagement in a particular cone of departure. Then there is discussion about Collision Interface and Transfer of Momentum.

And at the end, he tosses in a bit of lagniappe (a little something extra) and discusses when to add or combine speeds and how to deal with post-collision speeds.

(*Those chapter titles marked with an asterisk are available through IPTM as stand-alone publications that sell for $7.95 to $9.95 plus shipping and handling.. Through the efforts of Richard Hodge, IPTM's Editor Extraordinaire, those assorted chapters are likewise included in *Anatomy of the Collision: Third Edition* for only $44.95 plus s&h.)

To learn more about the content of the separate, individual publications, go to http://iptm.org/ and click on "Shop IPTM Online." On the left side of the screen is a menu of items beginning with "Articles" and "Books – Crash Investigation." Once you enter those links, it is a simple matter to scroll through the publications until you find one you like. Click on a picture of the publication and Voila!: a description of the chapters. You may also order by contacting the Institute of Police Technology and Management, University of North Florida, 12000 Alumni Drive, Jacksonville, FL 32224, or call (904) 620-4786 and ask for the Publications Department.

#

Fundamentals of Traffic Crash Reconstruction

by Daily, Shigemura, and Daily

Since the 1980s, the Institute for Police Technology and Management (IPTM) has been publishing top quality texts, such as Mike Lofgren's Handbook for the Accident Reconstructionist. Other authors include Al Baxter, George Bonnett, David Brill, Bob DuBois, Butch Kennedy, Frank Navin, and Bob Rivers, as they say, just to name a few. Let me digress a moment.
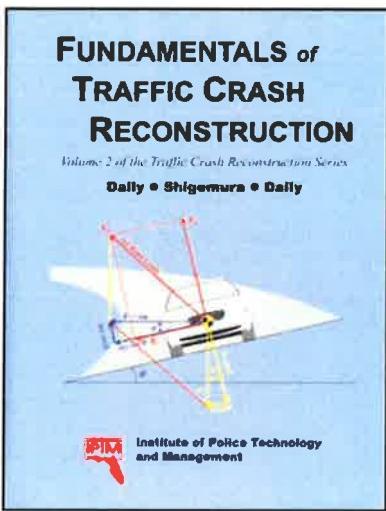
After nearly a decade since their Volume 1 of the Traffic Accident Reconstruction Series, together John Daily and Nate Shigemura finished Volume 2. But this time, the twosome became triplets. Assisting with the writing was Jeremy Daily, who recently obtained his Ph.D. and P.E. license. Jeremy believes that he brought an academic approach to the text.

He learned typesetting skills that provided a mechanism for the trio to write a highly technical and structured document without having to keep track of all the numbering. Furthermore, he says, all of the illustrations are mathematically correct because they were programmed into the document.

Jeremy adds that his first major effort was translating John & Nate's Fundamentals of Physics from WordPerfect to the new format.

Next, they focused on the crush and energy chapters and during 2005 John & Nate would spend weeks at a time at Jeremy's house writing the last chapters.

Jeremy said he thinks the most effort went into the Critical Speed Yaw chapter. He asked some hard questions and they "spent quite a while thinking and writing to address some of the questions we had. We did some physical testing and were able to generate examples from real life testing or crashes for the examples and exercises."

The elder Daily explains that one of their goals in writing the book was "To create both a textbook to use for classes as well as being a reference for those practicing in the field. To that end, we kept loose track of the various questions posted on INCR for the past few years. Many of these questions were basic in nature, and we wanted to create a reference in which these kinds of questions were answered. In addition, we designed the book for a variety of classes, from Vehicle Dynamics up through and including several advanced topics in crash reconstruction as well as the crash reconstruction course itself."

If you already have John's aforementioned 1988 book, you may wonder if you need this new one.

In a word, yes. I can almost guarantee that when you first see it (and heft it), you will relegate his old text to a hard-to-reach shelf and put the new one out front. Maybe even make a coffee table book out of it.

This latest work is a wonderful departure from IPTM's usual fare of spiral-bound books. This one has a hard cover. And massive! By actual weight, 4.5 lbs (2.04 kg), it is to my knowledge the heaviest, thickest book to come out of IPTM and it contains over 750 pages.

Fundamentals of Traffic Crash Reconstruction, Vol. 2 starts out with geometry, trigonometry and the dreaded calculus. If you're mathematically challenged, fear not. Aside from the traditional arithmetic operations and the more advanced manipulation of percentages, exponentiation and logarithmic functions, the book covers everything from coefficient of friction, off-tracking, and eccentric collision analysis using rotational mechanics.

They even cover "Rollover Taxonomy." (Don't feel bad; I had to look it up too.)

The authors revisit NHTSA's CRASH 3, for those too young to remember it, and they delve into drag sleds, and principal direction of force. Their equations are in both US and SI units plus they provide exercises (with answers!). And the book has an always invaluable index.

The cost is $75.00 plus shipping. Since this book will be sold worldwide, shipping costs vary. You can find the shipping costs at http://www.iptm.org/shipchart.htm.

You can order the book from www.iptm.org or by calling 904-620-IPTM (4786).

And would you believe, John, Nate & Jeremy have already put together another outline for their next book. Stay tuned.

#

Depositions: The Comprehensive Guide for Expert Witnesses

by Steven Babitsky and James Mangraviri, Jr.
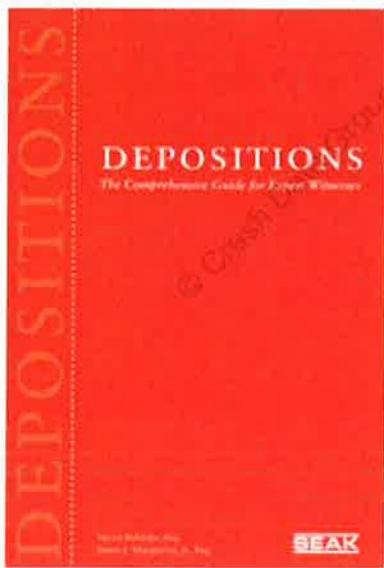
For some of you, that title may sound familiar. At least the authors' names may look familiar.

The reason is that those two gentlemen have written How to Become a Dangerous Expert Witness, The A-Z Guide to Expert Witnessing, Writing and Defending Your Expert Report, and Cross-Examination: The Comprehensive Guide for Experts, as well as a number of other books.

On the back of this latest text, it explains the book's reason for being: "The overwhelming majority of all testimony given by expert witnesses is given in depositions. This book shows expert witnesses how to excel during their depositions."

(I found that one of the book's better features is what it tells you NOT to do at depositions.)

For many of you, this 425-page book will be more of a refresher rather than a primer. In that case, consider this suggestion. Without actually reading every word on every page, notice that throughout each chapter, many pages have one or two "Practice Pointers" each consisting of a short paragraph. These are helpful hints the authors have found to be of benefit to experts before and during depositions.

One such Pointer states, "Experts should not be evasive at depositions. A good attorney will keep asking questions until the expert is forced to answer. Evasiveness reflects poorly on an expert."

Speaking of which, the authors caution readers to be careful during videotaped depositions, as they can be "quite useful to show a jury the expert's demeanor or evasiveness."

In addition, at the end of each chapter, a single sentence "Conclusion" sums up that chapter's topic. If you're pressed for time, just reading the Conclusion might cause you to go back and absorb the chapter more thoroughly later on.

Besides the Practice Pointers, recommendations and suggestions are sprinkled throughout the text. For instance, it depends on the jurisdiction where you are deposed whether you are given the opportunity to read and sign your transcribed deposition. Babitsky and Mangraviri offer schools of thoughts as to signing

or waiving signature. Of the latter option they note if you as the witness read and sign the manuscript you are "reaffirming your testimony and the transcription thereof and it will be much harder to explain away any parts of the transcript you might be impeached with later at trial."

If either retaining or opposing counsel requires you to read and sign, be sure to ascertain for the record who is going to pay for your time.

My wife is one of these people who always reads the last chapter of a book first. She wants to know if the butler did it. Or she wants to see who dies. Me? I look at the Table of Contents to see if any one chapter's title looks more interesting than the others do. In the case of Depositions: The Comprehensive Guide for Expert Witnesses, it was Chapter 8, "Setting and Collecting Your Fee."

Many attorneys choose to merely forward your bill to their client for payment. And many clients, especially some insurance companies, hold all invoices for 60 days or so before making payment. That way, they earn interest on the money instead of you.

Be sure you let the retaining attorney know that you are working for him or her, not their client.

Since this is a book about depositions, one question is addressed early on: Who is responsible for paying the expert's fee [for a deposition]?

Federal Rule of Civil Procedure 26(b)(4)(C) provides the answer:

> Unless manifest injustice would result, (i) the court shall require that the party seeking discovery pay the expert a reasonable fee for time spent in responding to discovery under this subdivision; and (ii) with respect to discovery obtained under subdivision (b)(4)(B) of this rule the court shall require the party seeking discovery to pay the other party a fair portion of the fees and expenses reasonably incurred by the latter party in obtaining facts and opinions from the expert.

If you have been deposed very often, you've probably been served – in person or by mail – with a subpoena duces tecum. If you are not familiar with Latin, the long definition is a writ or process including a clause requiring the witness to bring with him and produce to the court, books, papers, etc., in his hands, tending to elucidate the matter in issue. In short, it's a command to a witness to produce documents. One of those is usually copies of your billing invoices or statements.

A reminder from the authors to be sure to take those bills even if you don't retain copies since your company's bookkeeper sends them out. There is a stirring two-page Q&A exchange between an attorney and medical doctor who chose not to bring the billing documents because, "That's not something that I am involved with in my practice."

The lawyer puts the doctor on the defensive and as a witness it makes him look bad. The authors' Practice Pointer following the dialogue: "The witness has caused himself much difficulty by his

failure to bring the billing information and his inability to admit this directly."

Chapter 5, "What Experts Can Expect to be Asked," gives "examples of the most common lines of questioning experts can expect to face." One section is about the expert's qualifications. Having a slew of initials and degrees after your name often doesn't matter as much as hands-on experience.

In bold type and italics the authors write, "It is the authors' opinion that jurors are far more influenced by an expert's relevant practical experience, perceived honesty, and demeanor than the expert's academic record or lack of publications."

And for heaven's sake, if a lawyer sends you photos, an accident report and a slew of depositions to read, you should still ask to visit the crash site before deposition or trial. If you don't, the authors warn, "this may be portrayed by [opposing] counsel as a lack of thoroughness on the part of the expert witness."

The next chapter, "Deposition Advice for Experts" is one that "is a good idea to read ... immediately prior to being deposed."

Watch for "trap questions." An example offered is:

Q. Are you familiar with the literature in [your] field?

A. Yes, I am.

Q. Look at this list of 1,700 articles and tell me which ones you have read.

[Gotcha!]

Beware of using "absolute words." For instance, never, always, only, everything, all. They can come back to haunt you.

Chapter 11 (no relation to that Chapter 11) is titled "Truthfully and Artfully Answering Trick and Difficult Questions at Deposition." More than 25 pages containing 244 Q&A's that have a "Lesson" following each of the authors' reasons for the suggested answers.

You'll enjoy reading the sample deposition segments where the authors name names (deponents, attorneys, case citations).

Babitsky and Mangraviri advise against using "absolute words" when testifying. Absolute words restrict possibilities. Words such as no, never, none, always, every, entirely, and only imply the statement must be true 100% of the time and usually indicate "false" answers.

All kinds of tidbits and hints like that and more will come in handy for your next deposition.

The book, Depositions: The Comprehensive Guide for Expert Witnesses by Steven Babitsky and James Mangraviri, Jr., is available through SEAK, Inc., P.O. Box 729, Falmouth MA 02541. Customer Service: (508) 548-7023, Orders: (508) 457-1111, Fax: (508) 540-8304, Email: Mail@seak.com. Order online at www.SEAK.com.

From Crash To Courtroom: Collision Reconstruction For Lawyers And Law Enforcement

By John Kwasnoski
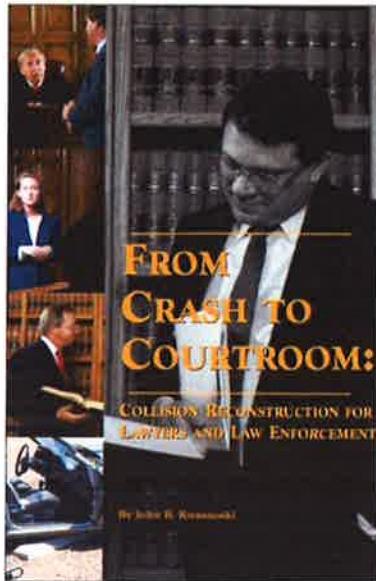
John Kwasnoski, Professor Emeritus of Forensic Physics at Western New England College in Springfield, Massachusetts, worked on a NHTSA-funded project to use automobile crashes as a basis for teaching physics, physical science, biology, math and driver's education topics at a high school level.

He went on to develop "CRASH! The Science of Collisions." No, this is not a computer program. It is a package of teaching materials and lab equipment that includes an actual drag sled, a 100-ft fiberglass tape, a steel tape, model cars and road templates, police and autopsy reports and all kinds of good stuff.

International Network of Collision Reconstructionists (INCR) member, Kwasnoski also writes books. In 1989 he co-wrote, with Michael Chieco, a trial preparation manual titled Establishing Liability in Vehicular Accidents. (That was back when they were still accidents. They have since been promoted to crashes.)

In 1998, he co-wrote Investigation and Prosecution of DWI and Vehicular Homicide; a year later he co-wrote Courtroom Survival: Making the Traffic Officer A Powerful Witness. Another co-written text was the 2003 book: The Officer's DUI Manual (each published by Michie/LexisNexis, Charlottesville, VA).

But now he has penned a tome alone. From Crash to Courtroom. The title sounds like a book just for lawyers, but nooo. Its complete title is From Crash to Courtroom: Collision Reconstruction for Lawyers and Law Enforcement.

The author gives one reason for writing the book this way: "While it may not be possible to educate the attorney to a level of understanding equivalent to that of the expert in a case, it is my goal in this text to help attorneys more closely scrutinize expert reports and to subsequently pose challenging questions for both their own and adverse collision reconstruction experts."

The book also helps educate the expert learn what sort of questions the attorney may ask. It may also assist in assessing the opposing expert's reasoning and conclusions. As the author puts it: "The differences of opinion of one expert with another expert, in many cases, pertain to assumptions made about input data or

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You can also rig the steering wheel to turn with the wheels.

Each car comes equipped with a camera positioned at the driver's point of view, one above the car looking down and one that follows behind the car.
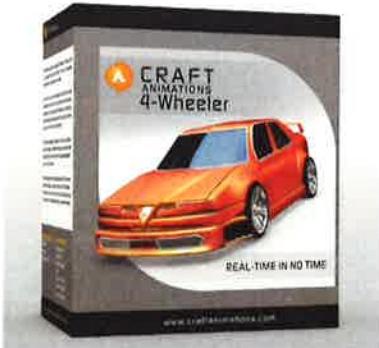
interpretations of field data." You obviously need to know where the other expert is coming from before you denounce his results.

Though it is merely my opinion, let me give you a downside of the book. While it has a comprehensive table of contents, there is no index, which makes it more difficult to look up stuff. However, if you read the book all the way through, you will have a good idea where everything is.

Although not a downside item, in referring to forces acting through the center of mass, Kwasnoski uses the word "concentric." Since technically that means "Having a common center or center point, as of circles," I suspect he means simply "centric" or centered. In his diagram for forces off center, he uses the word "Ecconcentric." That was a new one on Oxford, Webster and me. I suspect he meant "Eccentric" as in an eccentric thrust (Traffic Accident Investigation Manual, J. Stannard Baker, 1975, p. 316).

Or perhaps I'm just being eccentric.

If you are an active police traffic crash investigator and/or reconstructionist who testifies how crashes occur, judges and juries need to know that the science behind traffic collision reports is accurate. According to the publisher's own blurb, Kwasnoski's book "explains how many seemingly accurate findings may in fact be scientifically incorrect."

The publisher's promotional material notes that the book may also be helpful to cops and prosecutors because it teaches how to be more critical of collision experts' reports. "Equipped with a better understanding of the scientific fundamentals and analysis used in the preparation of such reports, attorneys may more effectively challenge the findings put forth by both sides. Cutting through the jargon and mathematical calculations frequently found in other automobile accident treatises, From Crash to Courtroom is written in non-technical terms to help attorneys better understand and more effectively question expert testimony."

John Daily, retired sergeant with Teton County (WY) Sheriff's Office says of Kwasnoski's latest book, "Every prosecuting attorney should have this on his shelf, just to make sure the police reconstructionist has everything in order, OR to see if the defense's 'hired gun' is actually obeying the laws of physics!" That means that if you are a reconstructionist, whether with law enforcement or engineering background, you also need to know if your work passes Newtonian muster.

Earlier, I mentioned a downside to the nearly 400-page book. Let me give you some upsides. An attribute I have not found in other texts is a question & answer feature.

Here are some of the questions:

Is there a way to intentionally misuse an accelerometer in a skid test so as to produce erroneously low readings?

Is it correct to add together the possible uncertainties in the measurements when they are used in a calculation?

Regarding slope measurement, does rounding down help

the operator?

Can post-impact skid marks be used to determine vehicle speed in a case where the weight of the vehicle has changed significantly during an impact?

Is it correct to assign a perception reaction time of 1.5 seconds to an operator for the purpose of reconstructing the events of a collision?

Obviously, you need to read the book for the answers.

Another upside, is that in his chapter on drag factor, he quotes from an article by some guy named Badger. (For some reason, Kwasnoski failed to mention Badger's first name.) And for those who question the accuracy of a drag sled, Kwasnoski writes, "When used correctly the drag sled gives comparable values to the accelerometer."

Moreover, the author devotes a section showing how it is possible to intentionally misuse an accelerometer in a skid test so as to produce erroneously low readings.

Besides drag factor, Kwasnoski's chapters cover evaluating the investigation report, lamp evidence, tire marks, and potential error in computer drawings. He produced a list of possible sources of evidence to determine who was (or was not) driving. There is a neat section on momentum and he shows you how some "experts" have misused computer programs (e.g., EDSMAC).

There is a section called "Deposition Checklist," designed for attorneys, for use in deposing expert witnesses. Read that list. Memorize it. Know the answers ahead of time and you will be ahead of the game.

Kwasnoski discusses topics from the basic concepts of physics to point of impact to reconstructing weather information. He gets into lamp evidence, tire mark measurements, propagation of errors in calculations, and road radius measurement.

The book is available through www.towerpub.com. If you are against giving credit card info online, call toll-free 800-969-8693, ext. 14, or fax them, also toll-free 800-264-3870. (You may print out an order form from the Web site.) The soft-cover book is $125, plus $7 s&h. but if you enclose payment with your order, there is no shipping and handling.

But wait. Mary Anne Hildreth, Tower Publishing's Managing Editor, has a deal for law enforcement. Tower offers police a $50 discount, available only if you call in and mention the police discount deal (and remember, the call is free). If you live in Maine, there is a minor thing known as your 5.5% sales tax, don't forget. Mailing address: Tower Publishing, 588 Saco Road, Standish, ME 04084.

If you think $75 is still too high, convince your prosecutor to spring for one. Then you can read his copy… on duty-time… next time you're in his office.

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Linear and Rotational Motion Analysis in Traffic Crash Reconstruction

By Orion P. Keifer, Richard V. Conte and Bradley C. Reckamp
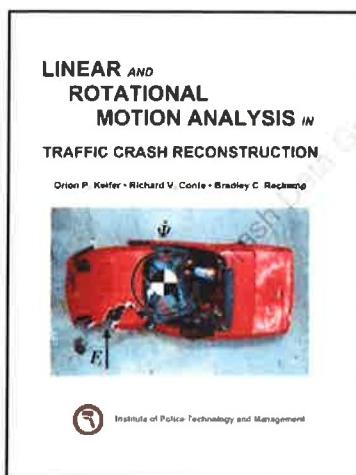
One of the newest books to roll off the presses at the UNF's Institute of Police Technology & Management (IPTM) is one titled Linear and Rotational Motion Analysis in Traffic Crash Reconstruction.

Let me warn you up front, this 232-page text is not for the faint of fractions, that is, the mathematically challenged.

No, it doesn't get into the quota rule, quadratic average, or quantum-limit cyclotron resonance line width due to an electron-phonon interaction. But the three authors, Orion P. Keifer, Richard V. Conte and Bradley C. Reckamp, all have Mechanical Engineering degrees. And they all eat formulae for lunch.

If you enjoy algebra and solving equations, you'll like poring over Linear and Rotational Motion Analysis in Traffic Crash Reconstruction.

Chapter titles include: The Physics of Traffic Crash Reconstruction, Inter-relationship of Linear and Rotational Momentum Exchange, General Rotational Momentum Equations, Rotational Friction, Rotational and Linear Motion Interaction.

The book covers some staged crashes and case studies, and wraps up with an Appendix that discusses – in depth and exhaustive detail – Tire Friction Force Analysis, Tire Linear Force and Moment Analysis, Vehicle Linear and Rotational Deceleration Equations.

Speaking of equations, Chapter 1 offers five equations to solve for yaw moment of inertia. The authors cite equations attributed to Rudy Limpert, Expert AutoStats, EDCRASH, and Neptune Engineering. They include also a yaw moment of inertia physics equation if you ever find yourself faced with a rectangular parallelepiped. And if that term snows you, it's "a polyhedron with six faces, each a parallelogram and each being parallel to the opposite face." Or, as the authors explain, it's engineering jargon for a box.

The book Linear and Rotational Motion Analysis in Traffic Crash Reconstruction is available only from IPTM. It's $35.95 plus shipping. Contact: Institute of Police Technology and Management, University of North Florida, 12000 Alumni Drive, Jacksonville, Florida 32224-2678. Phone (904) 620-4786, fax (904) 620-2453, E-Mail: orders@iptm.org. Online: www.iptm.org.

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How to Excel During Depositions: Techniques for Experts That Work

by Steven Babitsky and James Mangraviti, Jr.
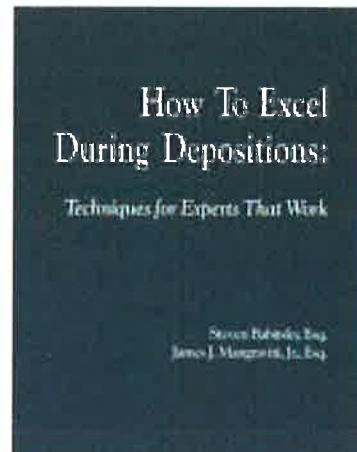
At first glance, it might appear that the book "How to Excel During Depositions: Techniques for Experts That Work" was written mainly for doctors. Wrong. Whether you're an engineer, an academician, or a law enforcement crash investigator, if you do accident reconstruction and end up in a deposition hot seat or on the witness stand in a courtroom, you should check out this book.

The 227-page text is appended with five appendixes and an index, for a total of 284 pages.

In case you ever wondered why we are deposed in the first place, well, according to the authors, "The theory is that if all parties know all there is to know about the other side's case, they will be able to evaluate the merits and weaknesses of the case rationally and settle the matter."

There are all sorts of interesting items in what's called the Federal Rules of Civil Procedure that you may search through at http://www.law.cornell.edu/rules/frcp/; however, Chapter One in "How to Excel During Depositions" covers the high points.

You will find over a dozen subsections under the topic "Dispositions and Discovery." Taking the time to review these would be worth your while, but authors Steven Babitsky and James Mangraviti, Jr. give you their insights on how to do well in depositions and not get caught off-guard.

Throughout the text the authors give you snippets of advice such as "Your role as an expert is not to argue evidence or procedure. You are not an advocate and will lose credibility if you appear to be one."

The authors offer many examples of typical questions and answers from depositions that end in valuable lessons such as "The expert's deposition testimony will be used to impeach him at trial if he attempts to change his answers on [an] issue" and "Expert witnesses are well advised to avoid flip, clever or joking remarks. Such remarks lessen your credibility as a witness and will accordingly lessen your value to the attorneys that retain you."

You may read the above lessons and say, "duh," because they seem so obvious, but you will be surprised how many of the lessons you may have forgotten… or haven't yet learned.

You will also read WHY the authors tell you to do things this way or that. For instance, they remind you that "It is your role as an

expert witness to provide your best, honest opinion based on the information that has been provided to you. It is not your role to resolve all factual disputes in the case." [Emphasis mine.]

They offer some instruction in the matter of handwritten notes. "Experienced experts have learned not to make such notations." However, if you make them, be careful not to destroy them lest you appear to be hiding something… and do NOT destroy them AFTER receiving a subpoena to produce.
There are other good tips under the heading "Private Notes" and "Cover Letters."

One more tip, if you work for a firm that does the billing, find out how much they bill in your cases so when it comes time to testify you'll know the amount. After offering a couple of exchanges from two depositions, another of the book's lessons states "Note how evasive the experts appear over questions that could have and should have been answered simply and directly."

Other valuable hints include those about not "getting burned" by off-the-record remarks made during breaks in your deposition. The authors also list some advantages and disadvantages to conducting the deposition in your office as opposed to the attorney's office or at some neutral location.

Have you ever been stiffed by an attorney who took your deposition and either didn't pay you at all or delayed sending payment for months? That's called "expert abuse." You may want to read Chapter 9 first. Under the heading "Abusive Questioning," it covers such topics as Repetitive Questions, Demeaning and Sarcastic Remarks. Then they discuss "Nonpayment of Fees." Good reading.

Speaking of fees, the book devotes all of Chapter Seven to "Setting Your Fee, Billing, and Collecting." Good luck.

You can read more about the book at http://www.seak.com/web-store/default.asp. You can even read a considerable amount of excerpts – free!

But get the whole book. It's $59.95 plus $9 s&h and available at the aforementioned website.

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How to Become a Dangerous Expert Witness
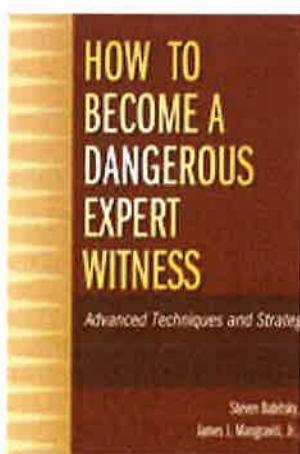
by Steven Babitsky and James Mangraviti, Jr.

First, let me tell you what I don't like about the book. The title. I don't have a problem with the material IN the book; it's the pesky title: How to Become a Dangerous Expert Witness.

Dangerous. What's that mean? With apologies to Ms. Browning, let me count the ways.

Alarming, fatal, risky, unhealthy, severe, rash, hazardous, unsafe, precarious, insecure, harmful, temerarious. That's enough. However, I don't think that's what the authors want to convey. I can guess their meaning but after reading the book, I prefer How to Become a Formidable Expert Witness.

Well, no, that might still suggest something dreadful or terrifying. Perhaps "well-prepared" or "experienced" or an "efficient witness."

The authors, Steven Babitsky and James Mangraviti, Jr. give their definition this way: "A dangerous expert witness is an expert witness who puts fear into opposing counsel."

I guess that leaves me out. I've yet to see an attorney quake upon seeing me enter the room.

Don't ask me why, but this is the second SEAK-published book that I started reading from the back. Perhaps it was because the book arrived here a few days before I was to be deposed and perhaps it was because one of the later chapters "Truthfully and Artfully Answering Trick Questions" caught my eye.

If you have been deposed several times, you have surely had an attorney foist a trick question on you. "Yes or no, have you stopped beating your wife?" is a good one.

The authors cite dozens of actual trick questions. Some examples include:

"You have stated your opinion. Is it possible that you are just plain wrong?"

"You enjoy the adversarial questions and answers in cross-examination, don't you?"

"Are there experts in the United States who are more qualified in this area than you are?"

"Do you know why counsel hired an expert witness who lives 1,500 miles from here to testify?"

"Do you consider yourself smarter than most of the people on the jury?"

In each of these – and dozens more – the authors offer three or four likely answers and they explain what's good, bad, or ugly about each one. It's a neat exercise. When you read each question, answer however you would, then look at the authors' comments. You'll be surprised.

In addition, you'll be educated and enlightened.

Chapter 2 is interesting. "To become a dangerous – [there's that word again] – expert, experts need to avoid giving opposing counsel any unnecessary ammunition." That's how the authors being their chapter on "Bulletproofing Yourself."

That same chapter has a section called "Fee and Billing Arrangements, Documents and Agreements" and it gives you a half-dozen

mistakes to avoid. Those are followed by several Q&A sessions that analyze and discuss why those mistakes could come back to haunt you.

Section 9, "E-mail address" points out how your e-mail address might not sound too professional. "Examples of unprofessional e-mail addresses are 'doctorweewee@msn.com' for an expert urologist, 'ohmyback@msn.com' for an expert chiropractor, or 'shrink@aol.com' for a psychologist."

In the accident reconstruction field, it may not be too wise to use 'Crashman@aol.com,' 'AccidentGenius@att.net,' 'WeWinYourCase@prodigy.com,' or 'SmashNcrash@netcom.com.'

There isn't anything wrong with them, but they tend to seem unprofessional.

Page 56 has this line: "Dangerous experts form and present bulletproof opinions. To do this, the authors recommend the following." Then this list 30 suggestions including "Document and photograph the investigation to help prove its thoroughness," "Never testify outside of one's true area of expertise," "Check and recheck relevant calculations."

Another recommendation is "Be well-trained and well-versed in any computer program used."

I mention that one specifically because more than once I have encountered police officers who have given calculations or diagrams in their reports yet they do not know anything about the software they used. One officer told me, "I don't know; it's whatever program the department has in the computer."

In examining an expert's training and background, Babitsky and Mangraviti cite this deposition exchange:

Q. Have you received any training in the use of the Rec-Tec Plus program?
A. No.

Q. Did you successfully complete the 40 specialized training videos on the Rec-Tec Web site?
A. No.

Q. Prior to me asking the last question, were you even aware that there were 40 specialized training videos on the Rec-Tec Web site?
A. No.

The authors add: "Dangerous experts are prepared to support their competency in the use of a computer program through experience, training, and the like."

Experts can sometimes be capital-B Boring and drone on and on. Jurors who get bored can nod off in a heartbeat. Visual aids can help, even when all it takes is for the expert to hop off the witness stand and draw something on a blackboard. Babitsky and Mangraviti note: "When oral testimony is combined with illustrative evidence, such as graphics, pictures or blow-ups of documents, jurors can retain up to 80% of the evidence being offered" [Emphasis theirs].

It appears that attorneys-to-be are taught in Circumvention of Law 101: "If you can't attack the evidence, attack the witness." The authors share with you tactics opposing lawyers use in depositions to rattle experts, make you look bad, make the deponent physically uncomfortable, cause the witness to lose his cool, and to intimidate the expert.

Because of that, you will want to read Chapter 5: "Defeating Opposing Counsel's Deposition Tactics."

Not only do the authors give you dozens of examples, they also offer a number of both good and bad responses.

In Chapter 6: "Hitting a Home Run During Direct Examination," you will read a list of 15 "hedge" words and expressions (e.g., apparently, I guess, as far as I can tell) to avoid during your testimony.

On pages 179-180 there are 40 tactics to help you defeat opposing counsel's cross-examination tactics. Chapter 8 explains in detail 60 or so offensive tactics experts can use against opposing counsel.

All in all, if you ever expect to testify as an expert witness, you might as well know what lawyers will throw at you so you can at least defend yourself. This book is a place to start.

You may read several excerpts by going to http://www.seak.com/webstore/dangerousexcerpts.htm.

The book How to Become a Dangerous Expert Witness is available online through www.SEAK.com, the Web site of SEAK, Inc., 316 Gifford St., 2nd Floor, Falmouth, MA 02540.

#

Cross-Examination: The Comprehensive Guide for Experts

by Steven Babitsky and James Mangraviti, Jr.

"All the world's a stage, and all the men and women merely players." ("As You Like It," (Act 2, Scene 7.)

Had Shakespeare attended criminal or civil trials in the United States today, he may have written: "All the courtrooms' a stage, and all the men and women merely players." For indeed, each person has a specific role to perform.
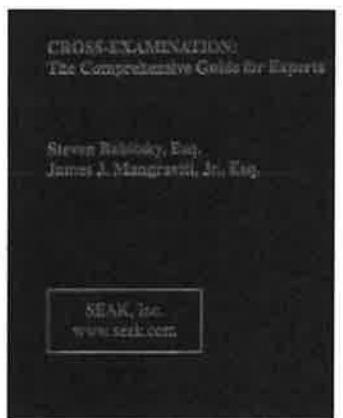
Often robed, one of the main characters, defined as "a public official authorized to decide questions brought before a court of justice," sits behinds an elevated "bench," gavel at the ready. Over to one side is a bailiff, an officer responsible for keeping order and maintaining appropriate courtroom decorum and has custody of

the jury, whose sole vocabulary consists of "All rise" and "Hear ye, Hear ye, this court is now in session; the honorable Judge _____, presiding."

Old School bailiffs might say "Oy yea, Oy yea," but the meaning is the same.

Then there are two or more individuals also known as barristers, counselors, mouthpieces, solicitors, attorneys commonly called lawyers – and a few other choice terms that are more descriptive. For the sake of this review, we'll call them the good guy and the bad guy. (They may both be gals, but let's not get all politically correct, okay?)

The good guy, of course, is the one who employed your services; the bad guy is the other one. We call him the bad guy because it's his (or her) job to somehow take you down a notch, make you look bad, and destroy your credibility, with an ultimate aim to discredit your testimony.

Moreover, the bad guy has even gone through several years of law school to learn how to do that. More about Bad Guy in a moment. Back to the courtroom.

Sitting off to one side is a panel of people whose part in this production is to pronounce the fate of the principal player: The Accused! The technical term for the group of folks is "The Jury!" They usually consist of a dozen citizens, plus a spare or two. Or there could be a half-dozen and one spare, depends.

There's a court reporter who may just sit there and hit "Record" on one kind of machine, or she (it's almost always a she) will type feverishly on a steno keyboard. That's a fiendish device comprised of 17 keys plus an asterisk and four vowels, giving you 4,194,303 possible strokes. If you use the number bar, your stroke number doubles. Other people may have duties in the courtroom, but those mentioned above are the main ones.

It is Bad Guy with whom you need to concern yourself, because his (or her) role consists of an alarming assignment, better known as the dreaded cross-examination.

A pair of attorneys, Steven Babitsky and James Mangraviti, Jr. – both Good Guys – undertook the task of making your concerns diminish. They did so by writing Cross-Examination: The Comprehensive Guide for Experts." This 414-page book will, according to the authors "help experts quickly and efficiently master the art of responding to each and every cross-examination question truthfully and artfully."

The way they do that is pose a huge variety of typical questions that you may expect during your cross-examination. Then they offer two sets of responses. Both sets are honest answers, but their examples point out why one type of answer is generally better than the other.

The authors give you some things to think about that the cross-examiner will attempt to get from you. Are you a hired gun? Is your testimony biased? Were your answers evasive? Are you argumentative? Do you appear overly nervous? Did you appear as though you were telling the truth? Does your opinion make common sense? Is your opinion consistent with the evidence in the case?

Keep in mind that "experts should consider the start of their cross-examination as an opportunity to make a second 'first impression' on the jury."

At the beginning of Chapter 5, "Advanced Cross-Examination Techniques for Experts," the authors list sixty-seven techniques to help you maintain your credibility and, potentially, strengthen your opinion. First, they list the obvious one: Tell the Truth.

Other recommendations include:

> Be yourself, unless you're a jerk,
> Don't look to retaining counsel for help.
> Do not be evasive.
> Do not argue with counsel.
> Pause and think before answering.
> Do not wake up the jury.

Let me dwell on that one. As the authors explain, "Jury duty is boring. … The jury has a limited attention span. They may not pay much attention to the expert's cross-examination. This is a good thing because cross-examination is not where the expert is likely to score points."

The authors continue by explaining how you can excel during this time.

As for being honest, the authors allude to John 8:32 without mentioning it by saying "Be consistent … the truth sill set you free."

They give several "lessons" throughout the text, such as "Wisecracks are not appropriate in court. They demean the process and make the expert look like a jerk."

What can you be expect to be asked on cross-examination? Read and dwell on Chapter 6: "What Experts Can Expect to Be Asked on Cross-Examination." This must-read 117-page chapter is full of examples and valuable lessons.

The next chapter titled "Legal Limitations to the Scope of Cross-Examination" is mostly for attorneys as it contains judges' rulings on dozens of cases where experts were permitted or disallowed to testify. You may wish to pick and choose to read only those cases that look interesting.

The book Cross-Examination: The Comprehensive Guide for Experts is available online through www.SEAK.com, the Web site of SEAK, Inc., 316 Gifford St., 2nd Floor, Falmouth, MA 02540.

C

RECONSTRUCTION
SEEING ACROSS THE YEARS

By Bill Wright

Working out the details of crash reconstruction can be a long and involved process. Reviewing the photos in this article, I was, on the on hand, struck by the observation of how much time had passed and how little had changed in the way we investigate these incidents. On the other hand, understanding a crash can happen in less than a minute regardless of when it was. In this incident, which took place more than 50 years ago, Florida Highway Patrol Sgt. Don Southerland was dispatched to a crash at an unidentified Florida crossroad. After arriving, he took several photos. Those photos contained all the evidence he needed to prove his case. Now it's time for you to stand in Sgt. Southerland's shoes. Look these photos over. Can you tell what happened in this crash?

EDITOR'S NOTE:

Sgt. Donald Southerland retired from the Florida Highway Patrol after 43 years of service. He currently lives in Jacksonville, Florida. His son, Don Southerland Jr., is also in law enforcement and can be reached at scoutman2@bellsouth.net .

Well known in the reconstruction community, Bill Wright created "TARO - The Traffic Accident Reconstruction Origin" website and has been a police crash reconstructionist, instructor and private consulting reconstructionists for more years than most people would admit....although he wasn't AT this particular crash himself! Recently, Bill was looking through a "shoe box" full of pictures and those related to this crash, as he put it, "jumped out at (him)." He said he was "...motivated to scan the photos, write a little introduction and pose the problem: here are the photos.

Can you figure this out?"

Bill Wright can be reached at bwright@tarorigin.com

So...can you?

View looking North
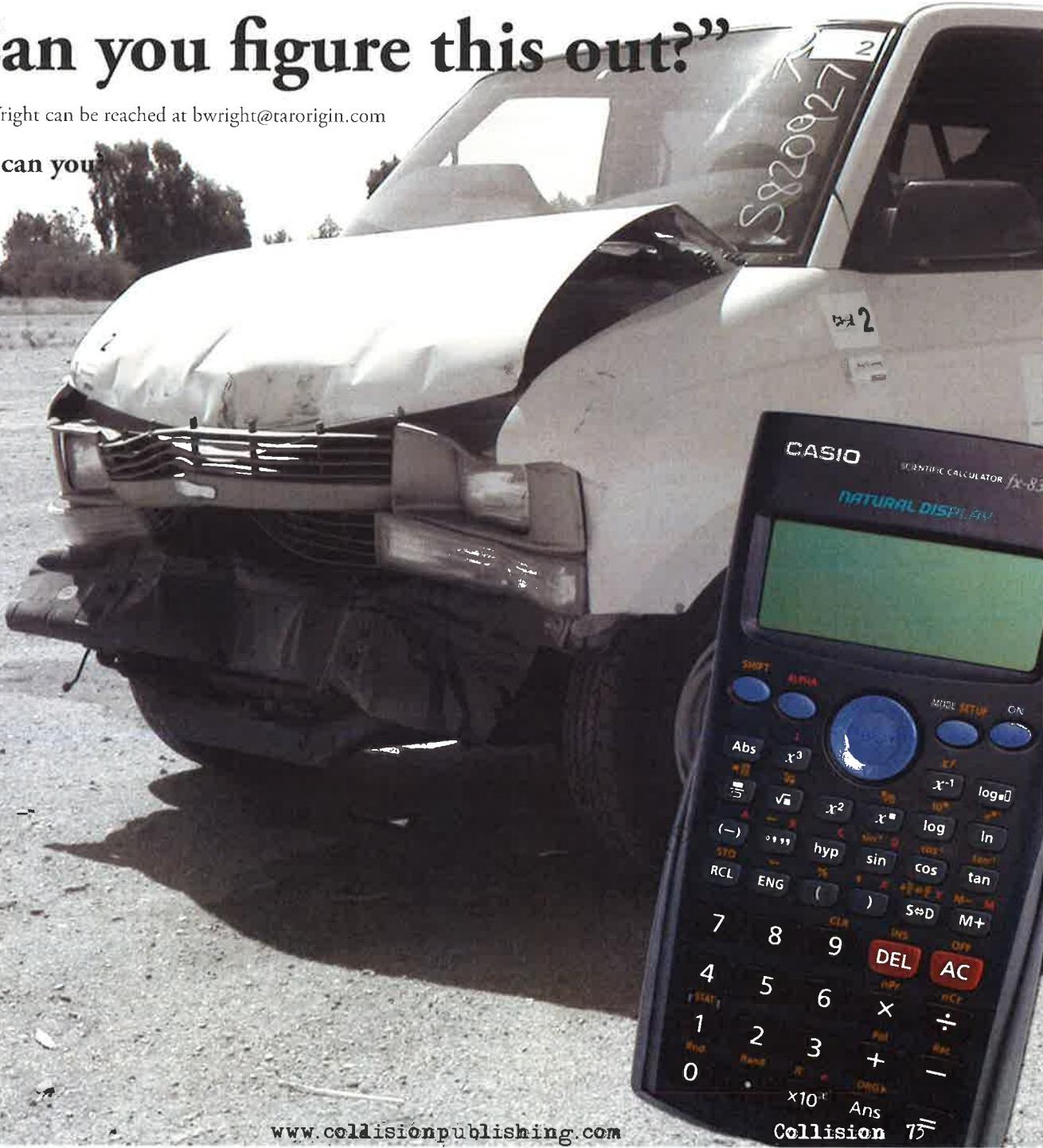
As I look back at this crash across the years, I'm confident that Sgt. Southerland's thought process in his analysis of this crash may well have developed something like this...

Upon examining the scene, note that the roads meet at right angles to each other and observe only one approach has a stop sign.

Looking at the vehicle damage evidence, we can see where the contact damage is located on each car (front of the Chevy (the station wagon) and side of the Packard). Note the damage profiles are similar in width and magnitude ad then fitting those contact surfaces together we can approximate the vehicle's orientation at impact. The vehicles collided oriented about 90 degrees to each other. Sgt. Southerland may have visualized this in his head. Others utilize their hands as car surrogates orienting them as in Figure 1.

Next, I suspect he contemplated a momentum analysis and began the process by considering the weights - probably close to about the same which then suggested they had similar delta-Vs. The scene tells us that departure directions were similar (northeast in the intersection) and since they might have spun, we can't rely on the direction the vehicles are found pointing to help determine their approaches. Since we do not know about spin yet, we ignore the directions that the vehicles are pointing for the moment.

The area of impact on the roadway, hopefully highlighted by indications such as gouge marks or collision offsets will have to be established. If there is no evidence to document point of impact, follow the departure paths back to the area where they converge. This should be, at least, the area of impact. Then, recall the contact damage match previously evaluated and find the only approach that fits the area.

One way to accomplish this is to place the vehicles as in Figure 1 and rotate them until the approach directions yield the observed departure direction. See Figure 2 below. At that point, we can use general momentum considerations to conclude which driver ran the stop sign (bet I was the Packard).

We might keep in mind something like: north and east pre-collision momentum should result in northeast post collision momentum. This is another way of saying momentum before equals momentum after (Chevy northbound and Packard eastbound).

Finally, we'd try to explain the direction the vehicles were found pointing at rest and look at the vehicle damage again but now assess the direction of force (PDOF). The Chevy displays an obvious damage offset to driver's right. This means a non-central impact and rotation. Offset damage is not as obvious to the Packard;however, the location of the damage (side), behind the center of mass also implies rotation. These non-central forces would cause the both vehicles to rotate clock-wise. This explains the rest position and orientation of both the Chevy and Packard.

It is worth noting that this may or may not have been the exact procedure Sgt. Southerland used some 50 years ago. But the photos indicate he certainly thought along those lines as he documented this crash to be able to illustrate most, if not all, of those concepts or bits of evidence.   I think, in most probably less than a minute, Sgt. Southerland understood his crash.

The message sent to us across the years is that his approach would work at a crash then, today and tomorrow. Of course Packards are not made anymore but that is exactly the point...
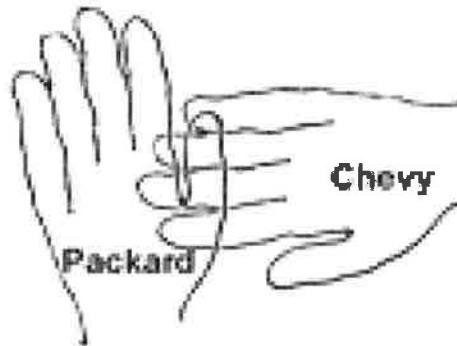
Figure 1: Using hands as car surrogates to help understand orientation at impact

Figure 2: Rotating the vehicle's damage match to find the solution that will yield the observed departure. The orientation at right is the only approach that yields the observed departure.

No   **No**   **No**   **Yes**

CDR GEAR

CDR-PSU

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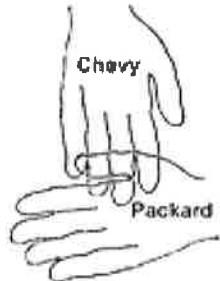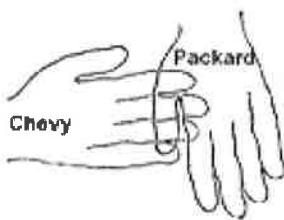
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Back Panel Detail

CDR-PSU OVERVIEW

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FEATURES

- The CDR-PSU is a sophisticated switching power supply that accepts a wide range of input voltages and produces a clean precise 12V output.

- The CDR-PSU is a compact, rugged tool designed for the real world.

- The CDR-PSU is fully protected against reverse battery conditions, shorts, under voltage conditions, over voltage conditions and electrical noise.

- The CDR-PSU at a glance provides the investigator with a "Power Good" indicator as well as a battery voltage.

Collision

The International Compendium for Crash Research

Tech Tips

Sean Haight
Editor
Collision Publishing

apturing Error Messages

C Since its introduction nearly 8 years ago there have been several attempts from various quarters to develop some sort of standard "protocol" or procedure for downloading data from airbag control modules. Some of these proposed "guideline protocols" included things like videotaping the computer doing the download which, with the CDR system, is really like video taping a radio playing music. There's no point in it if all you're planning on seeing is the download process... "...pass 1... pass2 ... pass 3... save recovered data?" Those familiar with the CDR system download process know it's really straight forward and that there are no surprises on the screen...unless.

Is there ever a time when "recording" something from a screen is important? Well, yes, there are times when capturing certain on-screen occurrences can be a valuable troubleshooting tool but a video recording of the process is different than a capturing specific troubleshooting messages. One can take pen in hand and write down the specific wording of an error message and there are other tools but a video is neither necessary nor would it, with any real level of assurance, routinely provide a clear view of the message.

Assuming the reader understands the process of running the CDR software and downloading data from an airbag control or power-train control module, then they also understand that, most of the time, a download works without a problem; that the process from connecting the cables to saving the recovered data is usually smooth and trouble free. But there are those times when things don't go quite as we'd expect or really, what we'd like to have happen.

When one of those times" occurs there is normally an error message, a small "pop up" window that will appear on the computer screen within the CDR program. These error messages are there for a reason. They're there to tell you something happened and give you a clue as to what it was and how it might be fixed. They may be a message generated by your computer's operating system (like Windows) or a message generated by an application (like the CDR program) when it can't understand or comply with a command you've issued by a mouse click or keyboard command.

For purposes of this discussion, an error message generated by the CDR software is displayed as a "dialog box" when an unexpected condition occurs. Within the CDR program, there are a number of dialog boxes written into the program to appear when the program runs into a condition where it can't continue the process the user's selected or intends it to run. At the same time, there are other error messages which may be a function of the operating system encountering a situation where it "stops" because of a unintended or unanticipated condition. Perhaps the most recent, commonly encountered of these messages within the CDR program would be where the new Microsoft Windows Vista operating system prevents the user's from seeing the "Help file" because of a missing Windows component; the WinHlp32.exe file. As seen in the figure accompanying this article, the error message has a header or source indication at the top of that dialog box that reads "Windows Help and Support." By comparison, one generated within the currently running program simply reads "collect data" and is accompanied by the red "X."

So, on the one hand, we have the potential for encountering CDR program generated error dialog boxes and then there are error dialog boxes which might be generated by the operating system and when, for example, printing, might be generated by a printer or printing system error. What we're left with is the need to identify (1) which system generated the error message and then (2) what do we know, from the error message, the problem actually is and (3) then what do we need to do to resolve it?

Any reasoned troubleshooting logic flow chart would include a step which might read "identify the exact wording of any dialog boxes the user saw when the error was encountered." The key words here are "exact wording." The exact wording will help the tech support person or the end user attempting informed self-help using the Help file identify the source and meaning of the dialog box.

In the CDR program, perhaps the two most commonly encountered error messages are related to communication between the technician's computer and "a module." As seen in the figure, one reads "no communication with interface" and the other reads "no
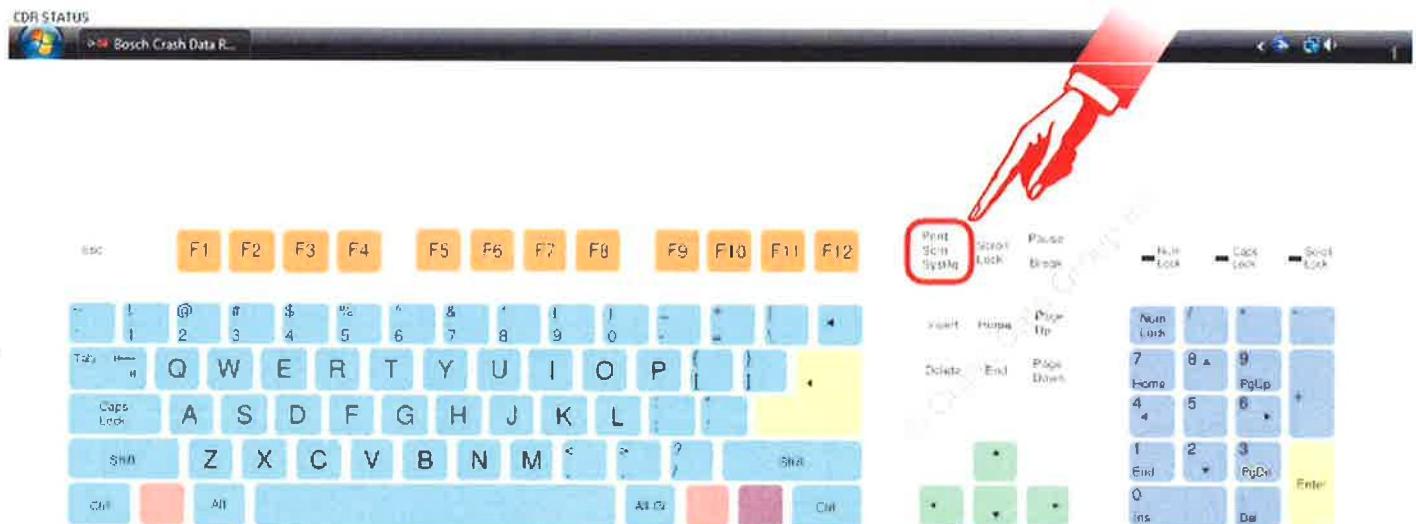
Figure 1: Print screen button location

communication with airbag (control) module." While similar, both have been reported in efforts to solve the problem as simply "I have a no communication error." Depending on which of these the Technician might encounter, there are different solutions.

Perhaps then the single most important step in meaningful troubleshooting is to be specific in terms of identifying the error message the end user encounters which brings us back to HOW to capture the exact wording.

The obvious first solution might be to go ahead and video tape the download. The reality of that is that video is often blurry and out of synch with the screen display. The second option and one often attempted is to take a photograph of the screen. Again, many of those are often difficult, at best, to actually read.

The best solution is to capture the message on screen, as it appears and store that actual screen for later review. To that end, there are two solutions.

The first is a utility available to all PC/Windows users: the "print screen" function. On your keyboard, normally in the upper right quadrant of the keyboard but different layouts may put this function elsewhere, you will find a key that reads "Prt Sc Sys Rq." The "Sys Rq" part of that key has an unrelated special function and should be ignored in this discussion. Microsoft has used SysRq for various OS- and application-level debuggers. For our purposes, we're interested in the "Prt Sc" portion.

"Prt Sc" is the "print screen" function. In short, when you push that key, the contents of the currently displayed screen are saved to the Windows "clipboard (in RAM)" and are available for the "paste" function within a program such as a word processor like Word or WordPerfect, programs like PowerPoint, Photoshop, MS Paint and even email clients like Outlook and Eudora. Everything displayed on the screen from the top to the bottom to include the task bar is captured to the clipboard and then, when pasted, becomes an embedded graphic in whatever program you "paste" it in to.

What this means is you've made clean, very readable copy of the screen where the error dialog box is displayed to include the clock display in the lower right hand corner, an indication of the programs running when the error was encountered. By expanding the system tray (near the time display in the lower right of your screen) you also capture the list of programs running "in the background." Another very useful tool for the troubleshooter.

Now, in a more clear, more complete, more concise format, you have made a record of the error message you encountered, you captured system information and whoever is doing the troubleshooting will be able to do a better, more efficient job of trying to solve the problem you encountered.

Another option, available users of the Windows Vista system is the Windows "Snipping Tool" found in the Start Menu in the Accessories folder. This tool, as seen in the figure with this article, enables the end user to capture all or part of the screen to the "Snipping Tool" application itself and then offers the end user the option of saving the screen capture directly from that application rather than going through a second program where the screen shot would be pasted.

No matter what the problem is or who is doing the troubleshooting, meaningful and effective troubleshooting starts with a clear understanding of the problem encountered and that usually means a complete and accurate recording - wether in pen and ink or through a screen capture - of the error message dialog box. From there, using the CDR Program help file or relying on someone more versed in the system (and perhaps the operating system) solving the problem encountered becomes far easier.
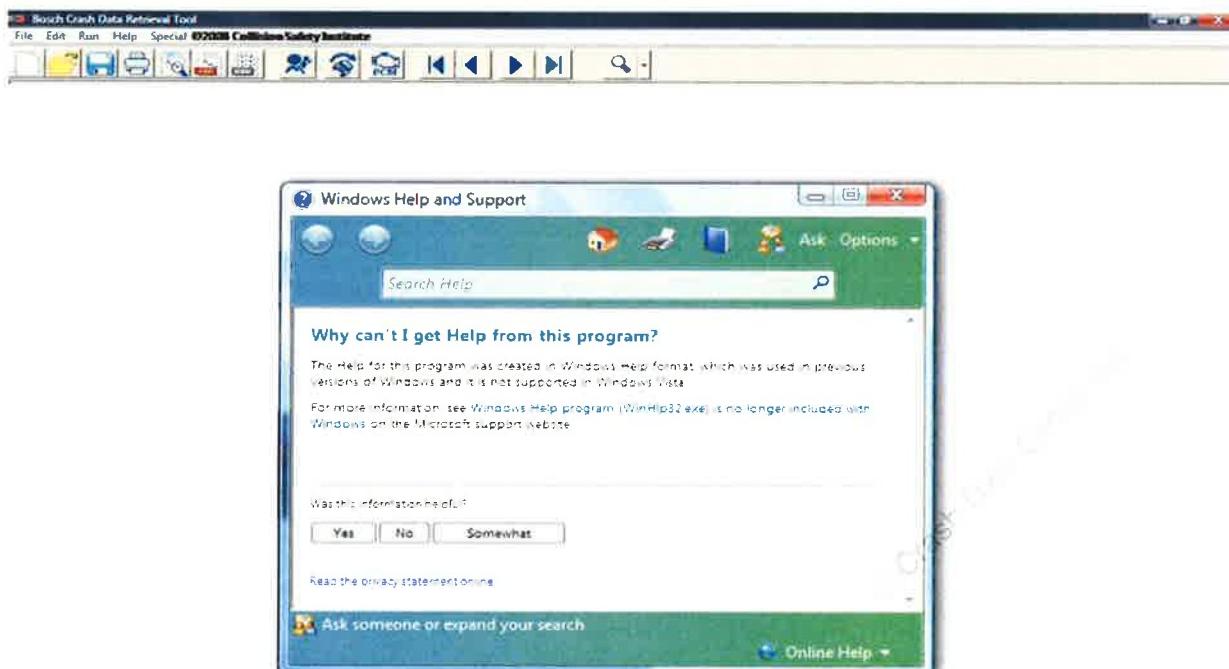
Figure 2: Help file formatting support screen

Making the Help File in CDR ver 3.0 work in Vista
When Microsoft shipped Windows Vista, they excluded a component that had been previously present in the Windows Operating system: WinHelp32.EXE. It a program that had been included with Microsoft Windows versions starting with the Microsoft Windows 3.1 operating system. However, the Windows Help program has not had a major update for many releases and no longer meets Microsoft's standards. Therefore, starting with the release of Windows Vista, the Windows Help program will not ship as a feature of Windows.

To view 32-bit "*.hlp" files, which is what's being used in CDR ver 3.0, the Technician must download and install the program (WinHlp32.exe) from the Microsoft Download Center. You will be asked to validate your copy of Vista. Most probably, for most Vista Home users, you'll probably want: Windows6.0-KB917607-x86.msu but if you choose the wrong one, your copy of Vista will tell you in an error window. You can also go to the Microsoft knowledge base on line and search for article 917607.

The CDR System's HELP file is a 32-bit hlp file. So this is a VIEW HELP FILE problem because Microsoft took OUT a function they've had as part of their OS going back a ways, not a "feature" in CDR.

But having the file alone is only one of the two things that the end user must do to get the CDR Help file to work under Vista.

First, of course, is to download WinHelp32.EXE from Microsoft. We do not have permission to distribute this file and you need the right one for your copy of Vista. You can find information on this file at:

http://www.microsoft.com/downloads/details.aspx?FamilyID=6ebcfad9-d3f5-4365-8070-334cd175d4bb&DisplayLang=en

Secondly, one has to manually edit the registry or apply registry patch to allow macros to work (CDR.HLP uses help macros which are disabled by default in Vista).

A registry patch file is found on the disk that comes with Collision Magazine which will automatically apply the changes to the registry. Note: We have not tested CDRVFIX.REG on every possible configuration under Vista so you use it at your own risk.

To manually edit the registry to enable macros in Vista, again, at your own risk, the end user will be changing the aprt of the registry that turns macros on or off in *.hlp files.

In Vista, click on the START button, enter "regedit" in the RUN command field add the following new subkey to the registry in this location:

HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\WinHelp

Add a DWORD value that is named AllowProgrammaticMacros to this subkey.

Set the value for AllowProgrammaticMacros to 1, the macros will be turned on. If the value is set to 0 or does not exist (blank) the macros will be turned off.

Yes, it's far easier to use the "regedit" mini-application with this issue of Collision but either approach will achieve the same goal: making the Help file display in Vista.

Bosch is working on a change to th architecture of the Help file so that, in future releases of the CDR program, there won't be a need for this sort of change in a setting in Windows.   **C**
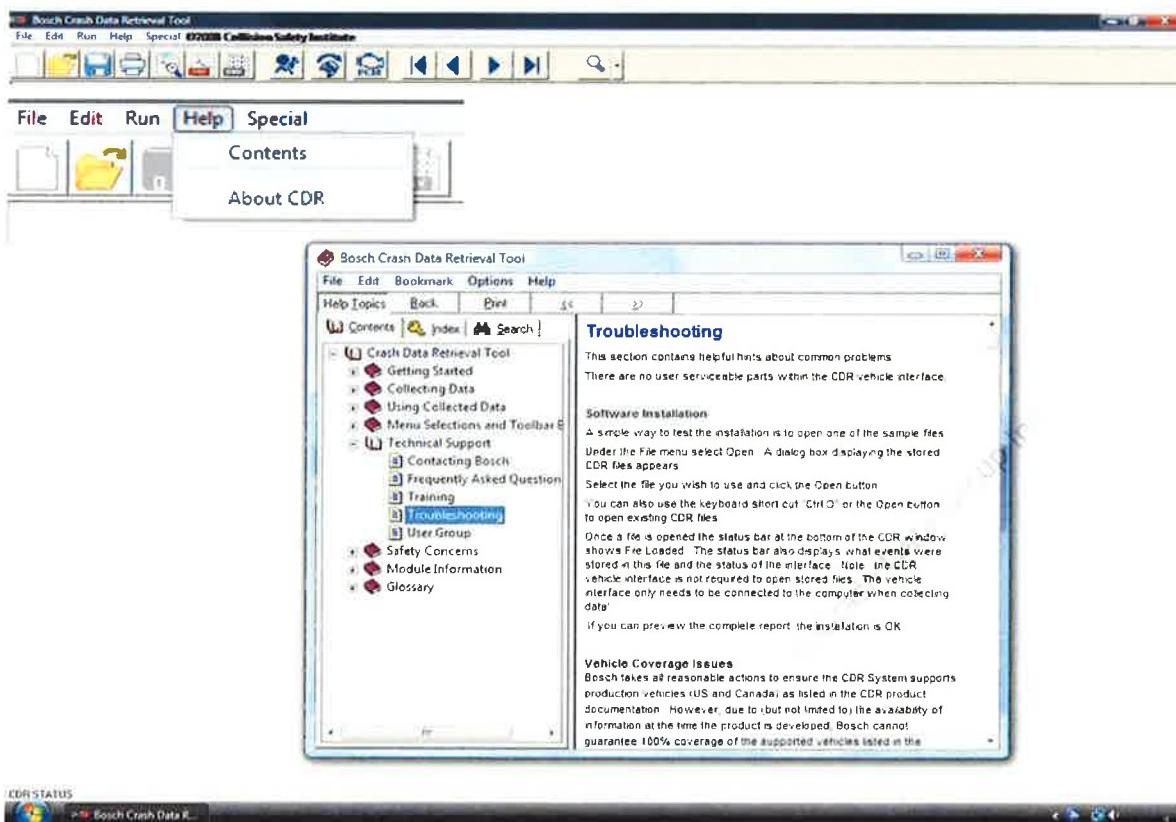
Figure 3: Troubleshooting guide location
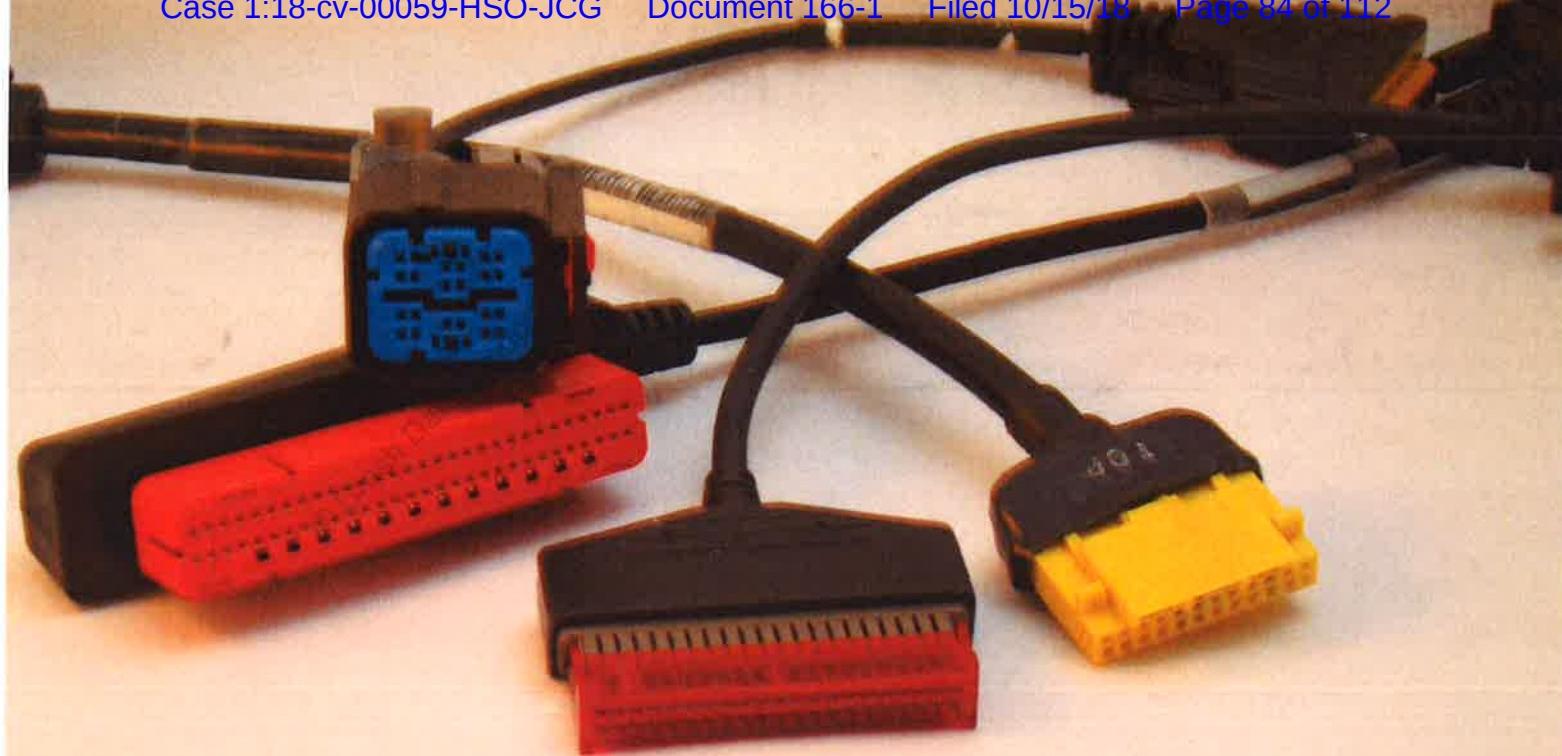
CABLE OPTIONS FOR THE "CDR SYSTEM HANDYMAN"

DAVID M. LITTLE
BAKER MATERIALS ENG. LTD

ditor's note:

This issue of Collision Magazine is primarily dedicated to the proceedings of the CDR User's Conference which was held in January 2008 in Houston, Tx. One of the topics of discussion at the user's conference and on the Yahoo! CDR User's Gorup has been the fact that some airbag control modules, while accessible through the DLC, aren't always supported - at least initially - by a direct-to-module umbilical cable. For those inclined to take on the challenges (and risks) of assembling their own cables, this Tech Tip by Dave Little of Baker Materials Engineering Ltd. will be both enlightening and useful.

There are three basic cables not currently part of the Bosch CDR System which may, from time-to-time be required for a direct-to-module download. These cables are for the GM SDMs known as the "I," "U" and "GS." The "I" is found in he 1996-2001 Chevrolet Metro, 1996-1998 Geo Tracker and the 1996-2001 Pontiac Firefly. The "U" might be found in the 1998-1999 Pontiac Trans Sport, 1998-1999 Chevrolet Venture and the 1998-1999 Oldsmobile Silhouette. The "GS" would be found in the 1999-2004 Chevrolet Tracker.

Dave's instructions here provide instructions for the pin outs for each of these cables and the photos here illustrate how he assembled the cables. The instructions are pretty straight forward. Each cable assembly will require a certain set of components and a little soldering skill. The instructions here only provide insight into which wire will be connected to which pinout and show the removal and installation he undertook to assemble these cables.

The author, David M. Little, P.Eng.can be contacted at Baker Materials Engineering Ltd., 2221 Manitoba St., Vancouver, B.C., 604-879-3585.

Figures 1-3: Detailed view of SDM - GS module
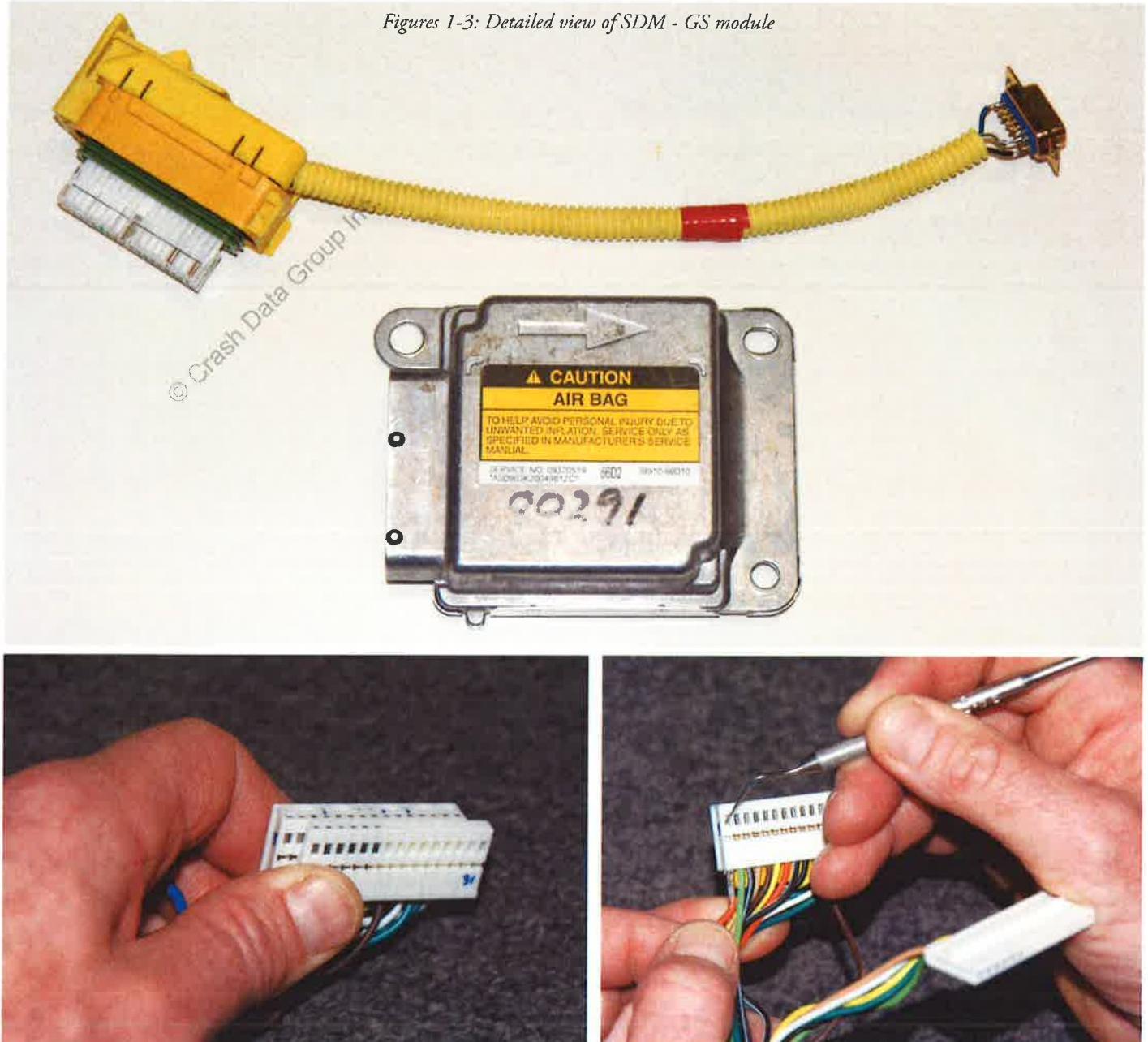
SDM GS

Vehicle coverage:
1999-2004 Chevrolet Tracker

Remove the SDM connector from the damaged vehicle.
Keep about a foot (30cm…) of wire attached. Buy a 15-Pin female serial connector.

Connect the following pin numbers:

At SDM	At CDR Interface	
A1	15	(+12V, blue/red wire)
A18	1	(Ground, black wire)
A4	9	(Data, white/black/silver wire)

Notes:
1. Wire colours may vary. Don't rely on colour. Rely on pin location.
2. Software versions 2.91 and 3.0 don't support this module. Use earlier or later versions.

SDM I

Vehicle coverage:
1996-2001 Chevrolet Metro
1996-1998 Geo Tracker
1996-2001 Pontiac Firefly

Remove the SDM connector from the damaged vehicle.
Keep about a foot (30cm…) of wire attached. Buy a 15-Pin female serial connector.

Connect the following pin numbers:

At SDM	At CDR Interface	
8	15	(+12V, blue/brown wire)
6	1	(Ground, black wire)
1	10	(Data, yellow/black wire)

Notes:
1. Wire colours may vary. Don't rely on colour. Rely on pin location.
2. The two yellow guides on the top of the SDM connection may have to be shaved off in order for the connector to fit in all models listed above.

Figure 4: SDM - I module
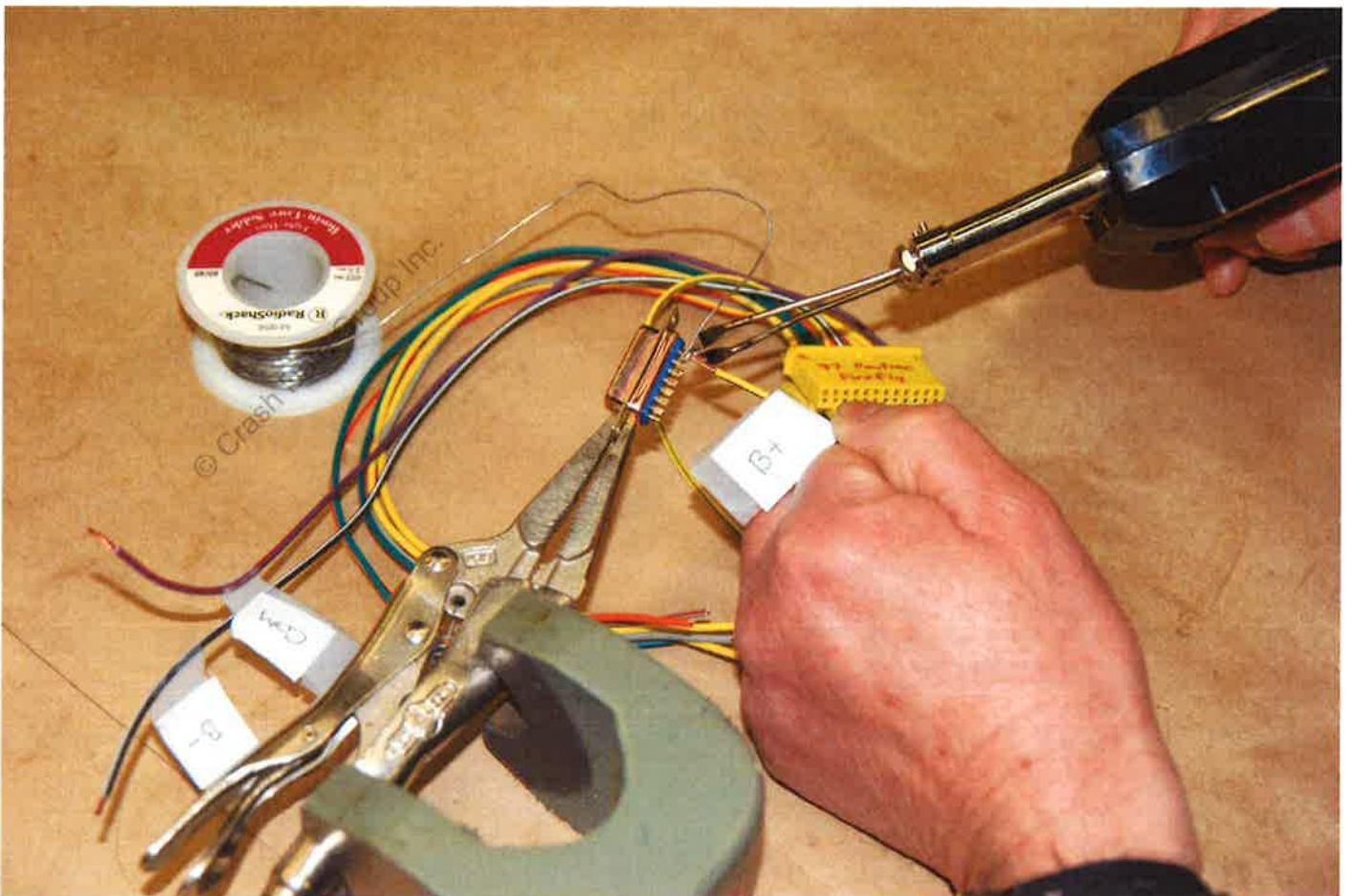
Figures 5 and 6: Construction of SDM - I module cabling
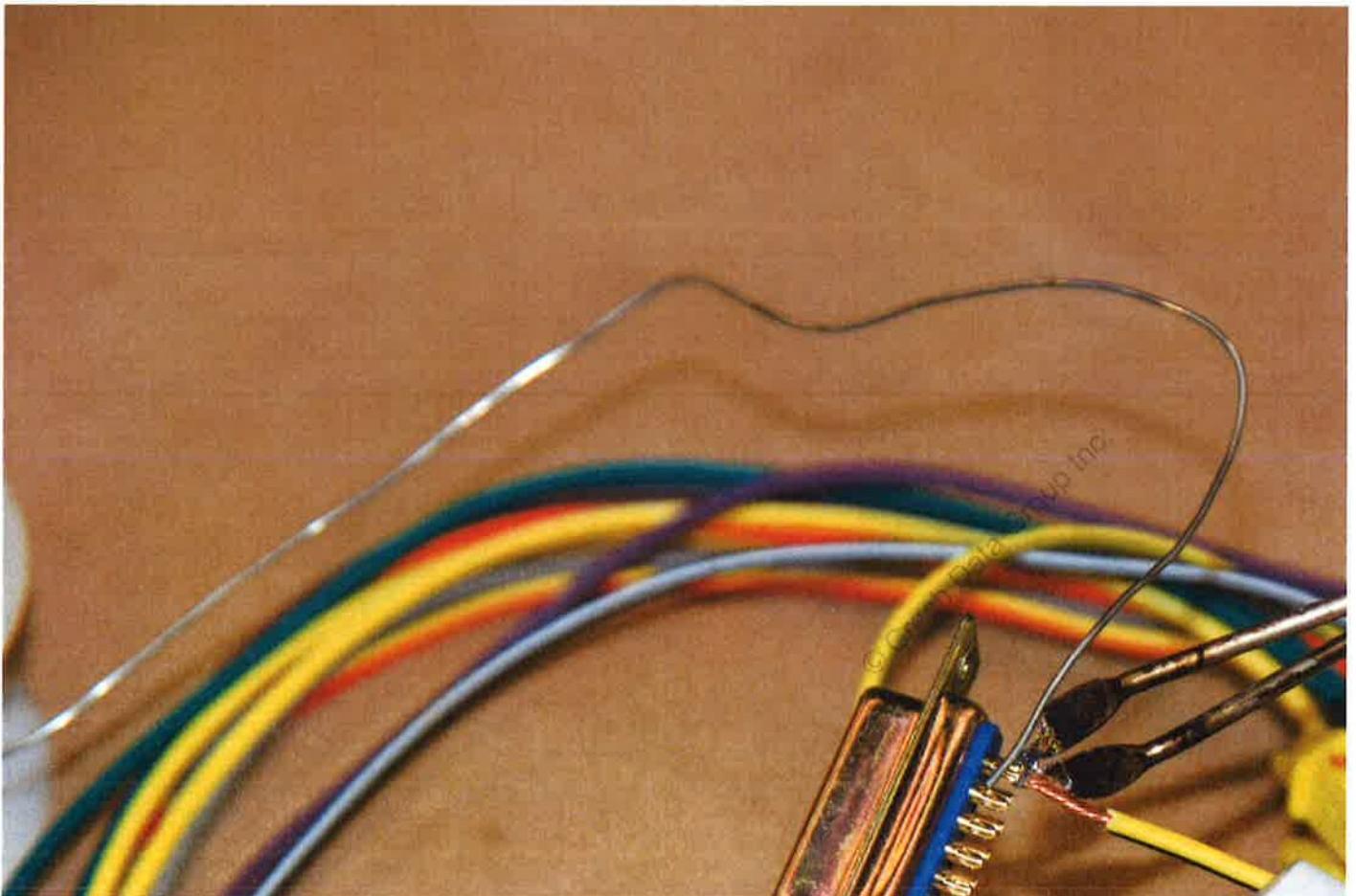
SDM U

Vehicle coverage:
1998-1999 Pontiac Trans Sport
1998-1999 Chevrolet Venture
1998-1999 Oldsmobile Silhouette

Remove the SDM connector from the damaged vehicle.
Keep about a foot (30cm…) of wire attached. Buy a 15-Pin female serial connector.

Connect the following pin numbers:

At SDM	At CDR Interface	
5	15	(+12V, yellow wire)
7	1	(Ground, black/white wire)
12	10	(Data, beige wire)

Note: Wire colours may vary. Don't rely on colour. Rely on pin location.

C

Figure 7: SDM - U module
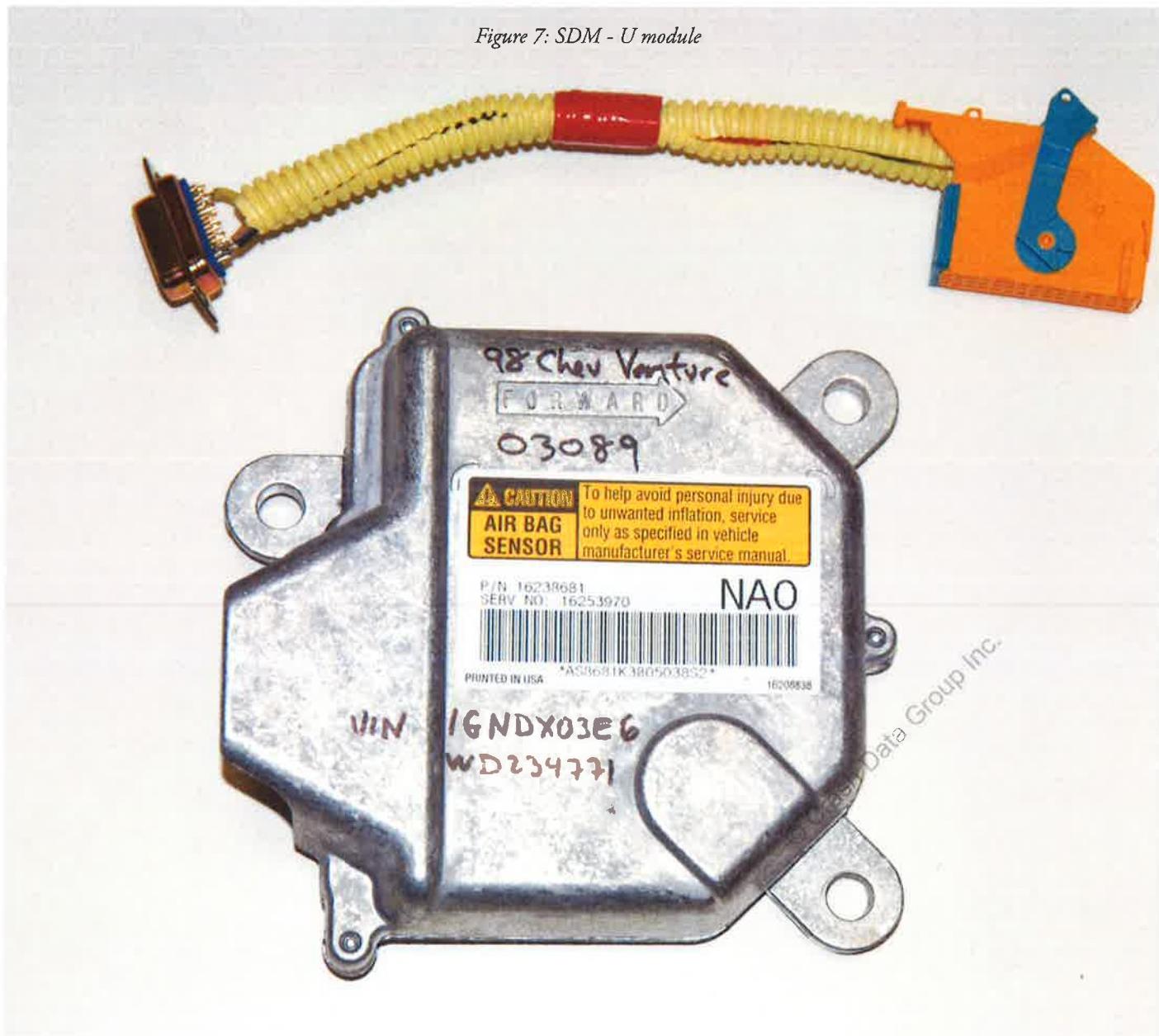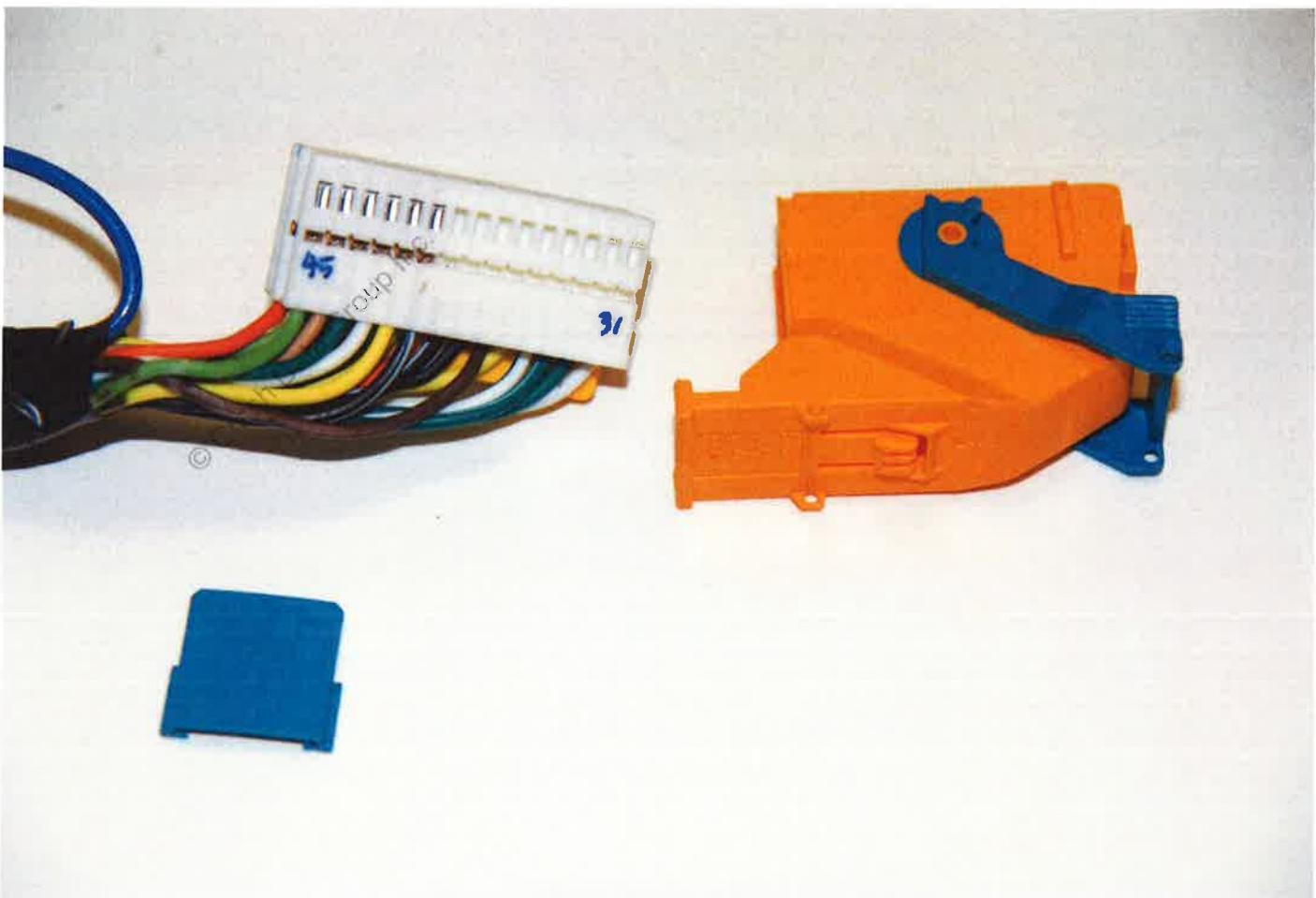
Figures 8 and 9: SDM - GS module cable housing
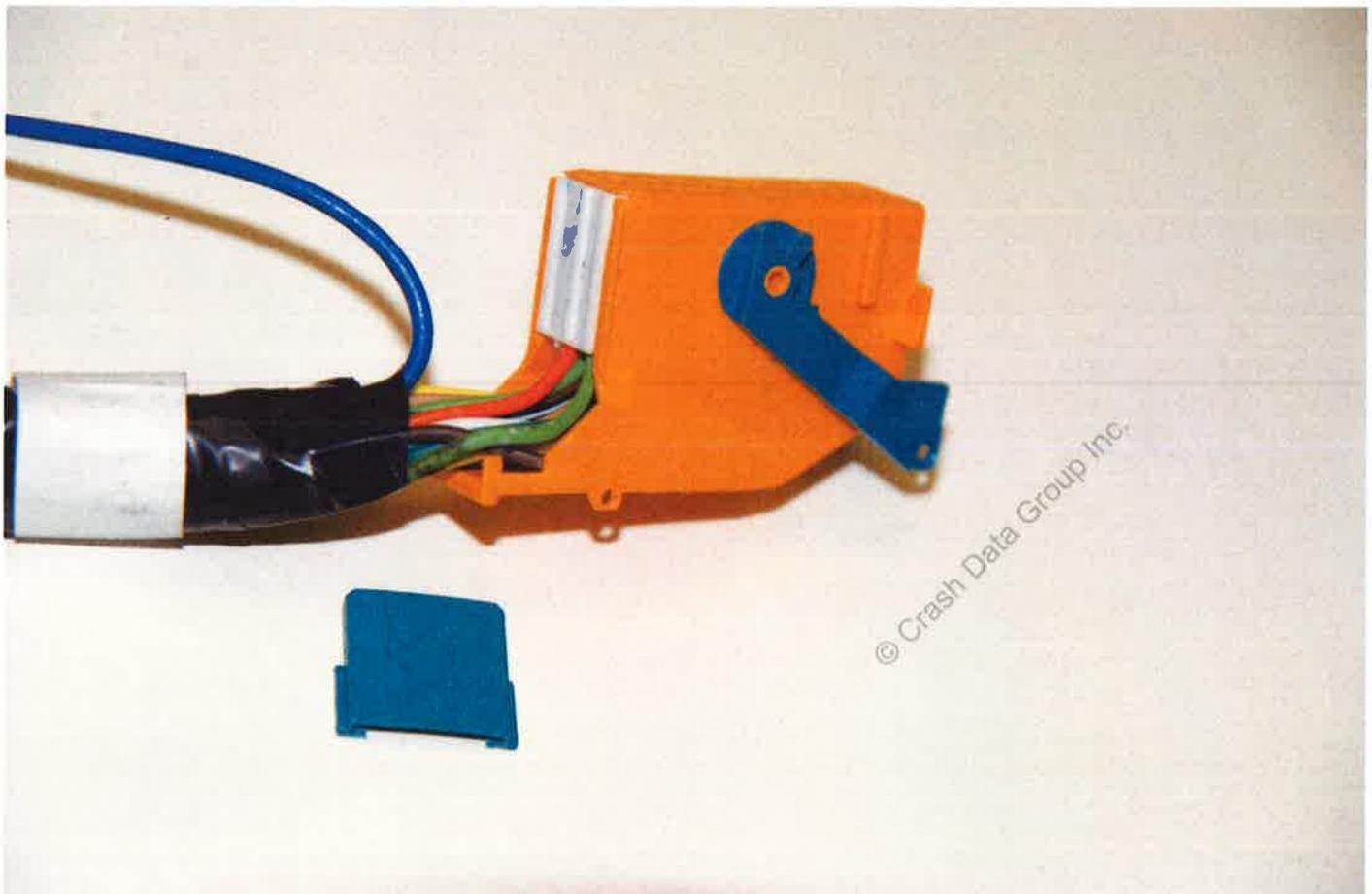
Comparing Different Sources of CDR Data in "Real World" Crashes

Sgt. Brad Muir
Ontario Provencial Police

I n the CSI CDR class, we talk about comparing the CDR data with a "situationally appropriate" reconstruction of the crash. "Situationally appropriate" takes into account many factors, including the availability of appropriate evidence, roadway, vehicle, etc. in order that the Reconstructionist be able to calculate impact speeds, delta-v, PDOF. Other factors such as the purpose of the investigation, i.e. to establish fault in a civil matter, determining criminal liability, vehicle safety research may also be considered. The investigators own level of training and experience must also be considered.

Sometimes overlooked is the ability to look at the stored crash data and perhaps use what is defined as "internal" data to calculate and compare against stored crash data that is defined as "external" data.

Internal data is that which is sensed and recorded internally to the Airbag Control Module (ACM) while External data is that which is recorded by the ACM, but comes from an external source. This external data is usually captured by the ACM off of the on-vehicle messaging network. Historically, internal data for comparison purposes consisted of the recorded delta-v, either as a value from the tabular information, or a maximum reported value from the data summary section of a CDR report. External data referred to the pre-crash information such as vehicle speed, engine RPM, throttle position and brake switch status.

With the additional coverage provided from the Ford Powertrain Control Module (PCM) we need to reconsider the internal vs. external reference for the Ford systems, and make our comparison from different types of information recorded in two separate modules on the vehicle.

This internal vs. external comparison does have limitations. It is best suited to those conditions where a closing speed analysis is also an option. These cases are normally limited to in-line type collisions, i.e. rear end or head on collisions.

The two cases below are both rear-end collisions. One, the GM case, involves a high speed rear-end collision to a stationary vehicle. The Ford case involves a lower speed rear end collision in a parking lot.

G M Case

This case involved a Pontiac Grand Am that was stationary on the right shoulder of a multi-lane controlled access highway. This vehicle was struck from behind by a Chevrolet Colorado pickup truck. The posted speed limit for this highway was 100 km/h (approx. 60 mph). There was sufficient scene evidence for the police Reconstructionist attending to calculate an impact speed for the Colorado. This scene evidence consisted primarily of post scene tire marks from the involved vehicles and the vehicle damage profiles. There was no evidence of pre-crash evasive action by the Colorado driver, and it was established that the Pontiac was well off the travelled portion of the highway, on the right shoulder.

The police reconstruction, using COLM, resulted in a calculated impact speed for the Colorado of 90 mph / 144 km/h. Several factors in the COLM analysis left room for interpretation. The post collision travel of the Colorado was primarily through a grass covered ditch, and there was an impact with the support post for a roadside sign. The roadway drag factor was determined at the time, as shortly after the investigation began rain fell and continued throughout the remaining time on scene.

Subsequently the ACM on the Colorado was downloaded using the Bosch Crash Data Retrieval Tool (CDR). The ACM on the Colorado, known as a Sensing and Diagnostic Module (SDM) had recorded a pre-Algorithm Enable (AE) speed for the Colorado of 94 mph (151 km/h) for all 5 pre-AE samples. This alone may provide an acceptable comparison for the Reconstructionist.

Taking it one step further, and to provide an additional means of comparison, a closing speed analysis was undertaken. The investigators determined that the Grand Am was parked on the
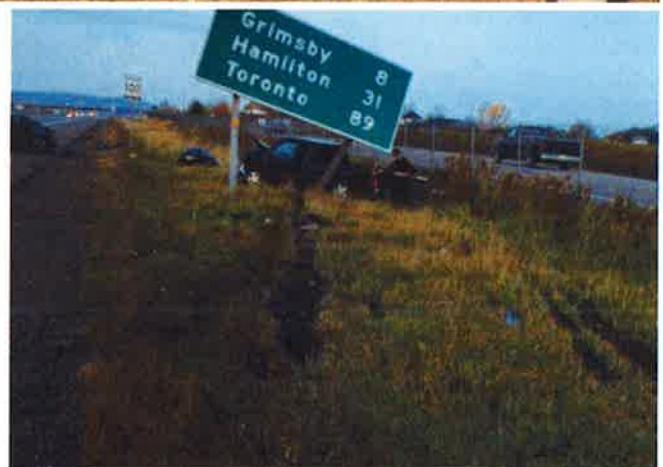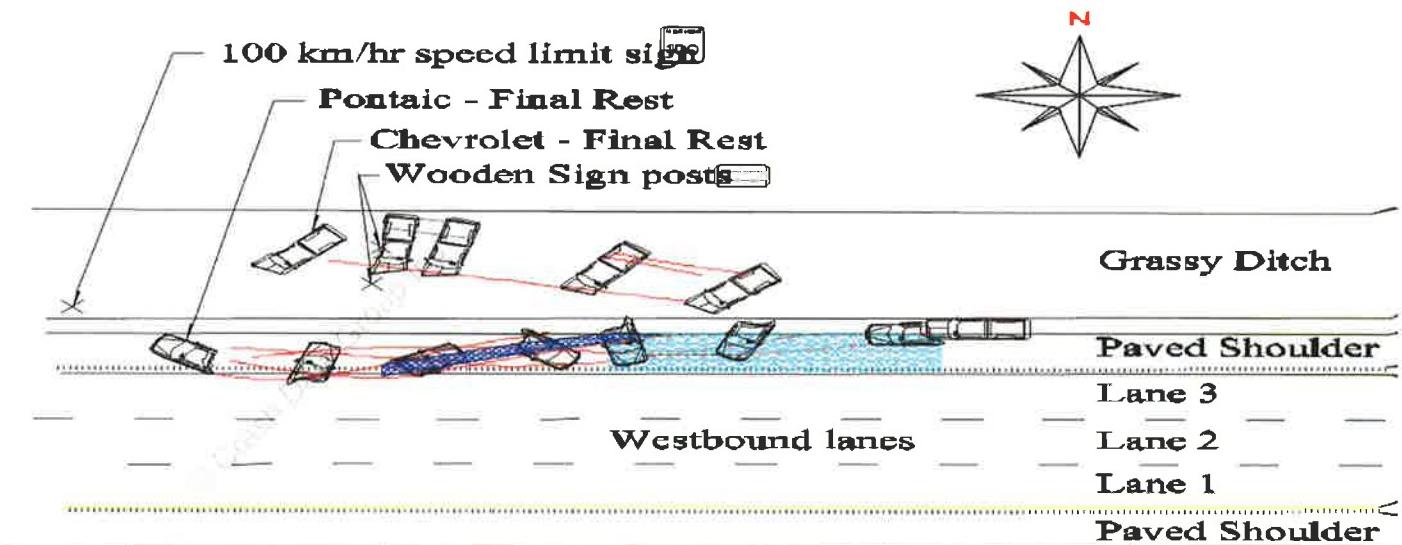
Figures 1-5: Drawing and photos from the GM case

Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle
-5	94	2944	47
-4	94	2944	47
-3	94	2944	47
-2	94	2944	47
-1	94	2944	47

Seconds Before AE	Brake Switch Circuit Status
-8	OFF
-7	OFF
-6	OFF
-5	OFF
-4	OFF
-3	OFF
-2	OFF
-1	OFF

right shoulder with the transmission in the Park position. The CDR download System Status at Deployment showed the Maximum SDM Recorded Velocity Change was 47.47 miles per hour. This generation SDM only records acceleration in the negative direction on the x-axis.

A Closing speed analysis requires the weights of the vehicles to be known as well as the delta-v for at least one of the vehicles involved. The Reconstructionist also has to take into account a restitution value (e) for the collision. The resultant value is the closing speed for the system. If the speed of one of the vehicles is known, then the impact speed for the other vehicle can be determined.

$$V_c = \frac{\Delta V_1 (W_1 + W_2)}{W_2 (1 + e)}$$

$$V_c = \frac{\Delta V_2 (W_1 + W_2)}{W_1 (1 + e)}$$

In this case the weights of the vehicle were determined from Transport Canada "WinSpecs" and 4N6XPRT AutoStats programs. The weight of the occupants was accounted for in both vehicles.

The closing speed calculated using a restitution value of .15 and was calculated to be 85 mph (137 km/h).

Conclusions: The impact speed of the involved Colorado was determined three ways. The Reconstructionist, using accepted methods (COLM) calculated an impact speed of 90 mph (144 km/h). The CDR download indicated a pre-AE speed of 94 mph (151 km/h) and the closing speed analysis yielded a closing speed of 85 mph (137 km/h). All three speeds were within a reasonable range of each other when the limitations of the analysis are considered.

Ford Case

This collision involved two police vehicles responding to a call for service. One vehicle abruptly stopped in front of the other, as was struck from behind. The struck vehicle was a 2004 Ford Crown Victoria Police Interceptor (CVPI) and the striking vehicle was a 2007 Ford Crown Victoria. Both vehicles had a published weight of 4100lbs (1860kg). There was considerable visible damage to the left rear of the struck 2004 CVPI. The apparent (visible) damage to the front of the 2007 CVPI was less than that of the struck vehicle).

Both vehicles were downloaded with the Bosch CDR system. The 2004 CVPI did not have an event stored in relation to this event. The 2007 CVPI had a deployment event recorded. This deployment event was stored as a result of the drivers' seatbelt pre-tensioner having deployed. As a result of this deployment, the PCM had received the Restraints Deployment Signal (RDS) from the RCM

System Status At Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Passenger Seat Position Switch Circuit Status	Rearward
Ignition Cycles At Deployment	6984
Ignition Cycles At Investigation	6989
Maximum SDM Recorded Velocity Change (MPH)	-47.47
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	172.5
Driver 1st Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	5
Driver 2nd Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	7.5
Passenger 1st Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	5
Passenger 2nd Stage Time From Algorithm Enable to Deployment Command Criteria Met (msec)	7.5
Time Between Non-Deployment And Deployment Events (sec)	N/A
Frontal Deployment Level Event Counter	1
Event Recording Complete	Yes
Multiple Events Associated With This Record	No
One Or More Associated Events Not Recorded	No

Figures 6 and 7: Photos from Ford case

and the PCM locked down 20 seconds pre-RDS and 5 seconds post-RDS (pre and post crash) data.

The RCM download for the 2007 CVPI in the System Status at Frontal Deployment indicates the RCM recorded a maximum change in velocity on its x-axis to be 12.71 mph over 217 milliseconds of algorithm run time.

The PCM download for the 2007 CVPI showed a speed change from 23.7 mph at time -.2 seconds, to 16.2 mph at the 0 sample (RDS received) and then 11.1 mph at the +.2 second sample. Figure 14 (PCM download tabular data for time around 0.0) Using the closing speed analysis in this collision, and a restitution value of .2 to .3 resulted in a calculated closing speed of 19 to 21 mph for the 2007 CVPI on the stopped 2004 CVPI in front.

Conclusions

We can see that when comparing the PCM recorded speeds, and the apparent speed change over the 3 samples, covering a time period of about .4 seconds i.e. from -.2 to +.2 seconds) to the RCM recorded delta-v, that even at a resolution of 5 samples / second, the sampling window must be considered when establishing an "impact speed". Given that there can be some delay between the PCM sending, and the RCM receiving, the RDS, it would appear that this collision occurred *AFTER* the -.2 second sample was recorded, but before the RDS was received. Once again there was very good agreement between the recorded pre-RDS speed (pre-crash speed) and the closing speed analysis. The higher resolution of the PCM pre-RDS data when analyzed with the delta-v also allows us a clearer picture of the events leading up to this collision and the speeds involved.

C

Figure 8: Photo from Ford case

Single Point Crush Variation

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John Perry, PhD

Judson Welcher BS, MS, ACTAR
Biomechanical Research &
Testing, LLC

A closed form solution relating changes in single point crush depth measures to crush based absorbed energy measures for the constant stiffness force-crush model.

Abstract
The subject study presents a set of closed form analytical solutions that relate the change in energy absorbed during vehicle crushing, based upon the constant stiffness force-crush model, to the change in crush depth for any singular nodal location for the general N-point equally spaced formulation. The equations derived are for the case of the change in crush depth for either of the endpoints of the profile or for a change in crush depth for one of the internal points. A worked example is provided to show the correct method of implementation for the subject formulation.

Introduction
Determining the velocities of vehicles involved in collisions based upon the residual damage present to the vehicles is a well accepted method in the field of motor vehicle accident reconstruction. All currently employed methods based upon the evaluation of residual damage as a measure of collision severity are premised in the context of one of the many mathematical models developed that relate the force required for the causation of residual damage to the quantified amount of residual damage present to a vehicle involved in a collision. The constant stiffness model, based upon the works of McHenry [1975] and McHenry and Lynch [1976ab], remains one of the most utilized of such mathematical models. The basis for this model has been reviewed previously [McHenry, 2001] and can readily be found in a number of learned texts [Cooper, 1990; Huang, 2002; Brach and Brach, 2005]. In brief, the model is predicated on the assumption of a linear relationship between the depth of crush present to an involved vehicle and the force, normalized per unit width of crush, required for its causation. Uneven crush profiles are modeled by discretizing the continuum crush profile at specific locations across the direct damage width and fitting the regions between these nodes using linear interpolation functions [NHTSA, 1982]. The absorbed energy is determined by the double integration of the force-crush relationship over the direct damage width and the crush depth. The forms of the resulting energy absorbed equations for two, four and six equally spaced nodal points have been published

previously [NHTSA, 1982; Cooper, 1990] and are relatively well known to practitioners in the field. Perhaps less well know is the work of the authors, in which a closed form solution for the energy absorbed equation was derived for any N number of nodal points [Singh et al., 2003a]. For the constant stiffness force-crush model, the resulting equation for the energy absorbed in crush causation, based upon an N point equally spaced formulation, is given by equation [1].

$$E = \sum_{i=1}^{N-1}\left[L\left(A\left(\frac{c_i + c_{i+1}}{2\cdot(N-1)}\right) + B\left(\frac{c_i^2 + c_i c_{i+1} + c_{i+1}^2}{6\cdot(N-1)}\right) + G\left(\frac{1}{N-1}\right)\right)\right]$$

[Eqn. 1a]

The notation and usage of equation [1] is relatively self-evident. However, for those unfamiliar with the notation, consider the following worked example for a three point (N = 3) equally spaced crush profile. The index term, i, in equation [1] is from 1 to N − 1 = 2. This thus represents two separate equations (one for i = 1 and one for i = 2) that are summed together. The two equations are:

$$(i = 1)\qquad E_{12} = L\left(A\left(\frac{c_1 + c_2}{4}\right) + B\left(\frac{c_1^2 + c_1 c_2 + c_2^2}{12}\right) + G\left(\frac{1}{2}\right)\right)$$

$$(i = 2)\qquad E_{23} = L\left(A\left(\frac{c_2 + c_3}{4}\right) + B\left(\frac{c_2^2 + c_2 c_3 + c_3^2}{12}\right) + G\left(\frac{1}{2}\right)\right)$$

[Eqn. 1b]

Summing these two equations gives the closed form analytical solution derived previously by the authors [Singh et al., 2003b].

$$E_3 = L\left(\frac{A}{4}(c_1 + 2c_2 + c_3) + \frac{B}{12}\left(c_1^2 + 2c_2^2 + c_3^2 + c_1 c_2 + c_2 c_3\right) + G\right)$$

[Eqn. 2]

For the two point equally spaced formulation, equation [1] reduces to a singular equation. For the four and six point formulations, there are three and five equations, respectively, that are summed together to produce the final form of the equation for the energy absorbed.

Recently, much attention has been given towards qualifying and quantifying the uncertainty associated with various tasks and numerical methods in the field of accident reconstruction [Brach and Dunn, 2004]. If the constant stiffness model coefficients are considered normally distributed stochastic variables, with non-zero mean and variance, a method has been derived to quantify the uncertainty associated with such a modeling process [Singh, 2004]. One may also approach the issue of uncertainty, in the subject context, by prescribing a range of values over a certain confidence interval for each input parameter and thereby determining a range of the likely amount of energy absorbed in crush causation. At times, however, one is left with the situations in which only singular values are provided for the input parameters. Such a situation would be exemplified by the case in which only a singular numerical value for a particular crush depth is provided.   It is within this context that the issue arises with the amount of change associated in the absorbed energy with increasing or decreasing a particular nodal crush depth (i.e. uncertainty within a singular nodal crush depth measure). While such calculations are readily conducted numerically using spreadsheet or analytical mathematics software programs, certain situations preclude the ready use of the same.

Objectives

The objective of the subject study is the analytical derivation of closed form solutions to the calculated energy absorbed during vehicle crushing as a result of a change in any singular crush depth for the general case of the N-point equally spaced force-crush model.

Analytical Methods

There are two general "types" of nodes that must be considered. External nodes, those being the first and last nodes in the discretizations, and internal nodes. The former are singularly weighted in both the linear and quadratic terms of the energy absorbed equations while the latter are doubly weighted. Equation [1] can be readily expanded by using the commutativity property of the summation operator.

$$E = \sum_{i=1}^{N-1}\left[\frac{AL(c_i + c_{i+1})}{2(N-1)}\right] + \sum_{i=1}^{N-1}\left[\frac{BL(c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2)}{6(N-1)}\right] + \sum_{i=1}^{N-1}\left[\frac{GL}{N-1}\right]$$

[Eqn. 3]

Equation [3] can be reduced using additional properties of the summation operator.

$$E = \frac{AL}{2(N-1)}\sum_{i=1}^{N-1}[c_i + c_{i+1}] + \frac{BL}{6(N-1)}\sum_{i=1}^{N-1}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right] + GL$$

[Eqn. 4]

The form of the solution presented for the external nodes will be the same. However, for the sake of completeness, the derivation will consider the two external nodes separately. Equation [4] can be expanded for the case in which the first node (j = 1) is removed from under the summation operator, the case in which the last node (j = N) is removed from under the summation operator and the case in which the jth node represents an internal nodal value (for the case in which N > 2) that is removed from under the summation operator. The resulting equations are given as [5-7], respectively.

$$E = \frac{AL}{2(N-1)}\left(c_j + c_{j+1} + \sum_{i=2}^{N-1}[c_i + c_{i+1}]\right) + \frac{BL}{6(N-1)}\left(c_j^2 + c_j c_{j+1} + c_{j+1}^2 + \sum_{i=2}^{N-1}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right]\right) + GL$$

[Eqn. 5]

$$E = \frac{AL}{2(N-1)}\left(c_{j-1} + c_j + \sum_{i=1}^{N-2}[c_i + c_{i+1}]\right) + \frac{BL}{6(N-1)}\left(c_{j-1}^2 + c_{j-1} \cdot c_j + c_j^2 + \sum_{i=1}^{N-2}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right]\right) + GL$$

[Eqn. 6]

$$E = \frac{AL}{2(N-1)}\left(c_{j-1} + 2c_j + c_{j+1} + \sum_{i=1}^{j-2}[c_i + c_{i+1}] + \sum_{i=j+1}^{N-1}[c_i + c_{i+1}]\right) + \frac{BL}{6(N-1)}\left(\begin{array}{l} c_{j-1}^2 + c_{j-1}c_j + 2c_j^2 + c_j c_{j+1} + c_{j+1}^2 + \\ \sum_{i=1}^{j-2}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right] + \sum_{i=j+1}^{N-1}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right]\end{array}\right) + GL$$

[Eqn. 7]

or each of these three cases we consider an original state in which the absorbed energy, E_o, is based on the original crush depth at the jth node of c_{jo}. Equations [5-7] can simply be rewritten by substituting E_o for E and c_{jo} for c_j. A linear change in value for the jth nodal crush depth can now be considered such that $c_j = c_{jo} + \Delta c_j$ in which the change in crush depth can be either positive or negative. Substituting the singular altered values for the crush depth for the jth node for each of the three cases results in the following:

$$E = \frac{AL}{2(N-1)}\left((c_{jo} + \Delta c_j) + c_{j+1} + \sum_{i=2}^{N-1}[c_i + c_{i+1}]\right) + \frac{BL}{6(N-1)}\left(\begin{array}{l} (c_{jo} + \Delta c_j)^2 + (c_{jo} + \Delta c_j)c_{j+1} + c_{j+1}^2 + \\ \sum_{i=2}^{N-1}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right]\end{array}\right) + GL$$

[Eqn. 8]

$$E = \frac{AL}{2(N-1)}\left(c_{j-1} + (c_{jo} + \Delta c_j) + \sum_{i=1}^{N-2}[c_i + c_{i+1}]\right) + \frac{BL}{6(N-1)}\left(c_{j-1}^2 + c_{j-1} \cdot (c_{jo} + \Delta c_j) + (c_{jo} + \Delta c_j)^2 + \sum_{i=1}^{N-2}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right]\right) + GL$$

[Eqn. 9]

$$E = \frac{AL}{2(N-1)}\left(c_{j-1} + 2(c_{jo} + \Delta c_j) + c_{j+1} + \sum_{i=1}^{j-2}[c_i + c_{i+1}] + \sum_{i=j+1}^{N-1}[c_i + c_{i+1}]\right) + \frac{BL}{6(N-1)}\left(\begin{array}{l} c_{j-1}^2 + c_{j-1}(c_{jo} + \Delta c_j) + 2(c_{jo} + \Delta c_j)^2 \\ + (c_{jo} + \Delta c_j)c_{j+1} + c_{j+1}^2 + \\ \sum_{i=1}^{j-2}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right] + \sum_{i=j+1}^{N-1}\left[c_i^2 + c_i \cdot c_{i+1} + c_{i+1}^2\right]\end{array}\right) + GL$$

[Eqn. 10]

The change in absorbed energy for each of these three cases is calculated simply by taking the difference between the solution for the formulation based on the altered crush depth and that based upon the original crush depth at the jth node. We introduce the following notation for the constant terms multiplying the linear terms and quadratic terms, respectfully, in the absorbed energy definitions.

$$C_1 = \frac{AL}{2(N-1)}$$

[Eqn. 11]

$$C_2 = \frac{BL}{6(N-1)}$$

[Eqn. 12]

The change in absorbed energy thus becomes:

$$\Delta E = C_1\left(\Delta c_j\right) + C_2\left(\Delta c_j^{\,2} + \left(c_{j+1} + 2c_{jo}\right)\Delta c_j\right)$$

[Eqn. 13]

$$\Delta E = C_1\left(\Delta c_j\right) + C_2\left(\Delta c_j^{\,2} + \left(c_{j-1} + 2c_{jo}\right)\Delta c_j\right)$$

[Eqn. 14]

$$\Delta E = 2C_1\left(\Delta c_j\right) + C_2\left(2\Delta c_j^{\,2} + \left(c_{j-1} + 4c_{jo} + c_{j+1}\right)\Delta c_j\right)$$

[Eqn. 15]

The form of equation [13] and [14], as shown above, is the same with the change in absorbed energy being a function of the changed external crush depth, the crush depth at the adjacent node and the amount of change in the crush depth at the affected node. Equation [15], the closed form analytical solution for the change in absorbed energy secondary to the change in crush depth for an internal node, is affected by both adjacent nodal crush depths, the crush depth at the node in question and the amount of change at the affected node.

A potential subsequent step in a reconstructive analysis following the determination of the absorbed energy is the calculation of the energy equivalent speed (EES) or barrier equivalent velocity (BEV). Because the BEV is a function of the square root of the absorbed energy, a simple analytical solution for determining the change in the BEV as a function of the change in a singular crush depth is not readily reducible.

$$\Delta BEV = BEV - BEV_o = \sqrt{\frac{2}{m}}\left(\sqrt{E} - \sqrt{E_o}\right)$$

[Eqn. 16]

Worked Example

Consider the New Car Assessment Program (NCAP) test, v2749, for a 1998 Ford Explorer 4-door utility vehicle. The test in question consisted of a 151.3 slug vehicle impacting a fixed, massive instrumented barrier at a speed of 51.3 ft/sec in the full-engagement front impact mode. Utilizing a damage onset speed of 3.67 ft/sec and a seven point unequally spaced constant stiffness force-crush formulation [Singh, 2005, 2007] the constant stiffness force-crush coefficients of A = 241 lb/in,

B = 155 lb/in^2 and G = 187 lb were determined. We now consider a hypothetical original case involving a six point equally spaced formulation (N = 6) with a direct damage width of 64.8 inches (L = 64.8 inches). The constant terms defined by equations [11] and [12] are thus 1561 lb and 335 lb/in respectively. For a hypothetical crush depth profile, shown as the first line of Table 1, the crush depth can be varied at either an external or internal location and the corresponding change in absorbed energy can be calculated directly by implementing equation [1] and subtracting the energy absorbed using the original crush profile or by implementing the appropriate equation from [13-15].

Index									
1	2	3	4	5	6	E (in-lb)	ΔE_c (in-lb)	ΔE_a (in-lb)	%ΔE
5	6	8	8	6	4	332758			
6	6	8	8	6	4	340007	7249	7249	2.18
7	6	8	8	6	4	347926	15168	15168	4.56
5	6	8	8	6	**6**	346587	13829	13829	4.16
5	6	**10**	8	6	4	372462	39705	39705	11.9

Table 1. The effects of changes in singular crush depth values and the corresponding changes in the energy absorbed by the vehicle structure. The first line shows the original case for the subject example. Subsequent lines show individual cases in which a singular crush depth (shown as **bold** text) is changed from the original case. The energy absorbed is calculated and the change in energy with respect to the original case is determined both from the calculated energy absorbed (ΔE_c) and the subject analytical formulation (ΔE_a). The percent change in energy is based on the relative difference normalized to the original absorbed energy.

Discussion & Conclusions

The subject study was narrowly focused on the development of simple and easily implementable forms of the change in absorbed energy equation for the change in any single crush depth measure for any N-point equally spaced discretization scheme. The results of the implemented analytical methods, shown by equations [13-15], followed the expectations of the authors in two regards. The first was that the change in absorbed energy secondary to the change in crush depth at any particular index in the profile was dependent not only upon the crush depth changed but also the adjacent crush depths. For the external indices (1 and N) this was evidenced by the dependence of only one additional crush depth (2 and N – 1) while two nodes in addition to the changed node were required for consideration for internal nodes. The second observation was that for any given amount of change in the crush depth for a given initial value, the change in absorbed energy was greater for an internal node when compared to an external node. Such an expectation was based upon the form of the N-point formulation in which internal nodes are double weighted in both the linear and quadratic terms.

The subject paper provides a relatively simple solution for a very specific accident reconstruction task that in the broadest sense is of great import. The greater issue being one of determining the quantifiable level of uncertainty associated with various accident reconstruction tasks. In a potential case that could be perhaps considered optimal, all input variables for a particular calculation

would be treated as being stochastic in nature secondary to the inherent uncertainty generated by the measurement processes. One such approach in this regard is to model the input parameters as being normally distributed with a finite mean and variance as done by the lead author previously in regards to deriving the constant stiffness force-crush model parameters from full-width front to fixed, rigid, massive barrier test data [Singh, 2004]. An alternative approach and certainly one that is simpler to implement consists of assigning a lower and upper limit for each input variable. Implicit in such an approach is that the bounds are chosen over a specific confidence interval by the reconstructionist. The dependent variables of relevance can then be calculated over the full range of all of the independent variables. As an a priori approach, this method would be preferable as it lends itself rather easily to software based computation. The subject method, to be utilized under the strict constraints of singular valued crush depth measures in which the other system parameters are taken as known, provides a method for rapidly determining a measure of uncertainty in the absorbed energy calculation when such a calculation cannot be readily or easily evaluated.

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Nomenclature

A	Constant stiffness force-crush model crush resistance coefficient (lb/in).	
B	Constant stiffness force-crush model linear slope measure (lb/in2).	
BEV	Barrier equivalent velocity (ft/sec).	
BEV_o	BEV based upon the use of the crush depth of c_{jo} at the jth node (ft/sec).	
C1, C2	Constant terms in units of (lb) and (lb/in) respectively.	
E	Energy absorbed by a vehicle during the process of crushing (in-lb).	
EN	Energy absorbed by a vehicle during the process of crushing based upon an N-point equally spaced node scheme (in-lb).	
E_{ij}	Energy absorbed by crushing of a vehicle within the direct damage zone defined by the ith and jth node (in-lb).	
E_o	Energy absorbed by crushing of a vehicle based upon the use of the crush depth of c_{jo} at the jth node (in-lb).	
EES	Energy equivalent speed (ft/sec).	
G	Constant stiffness force-crush model constant of integration (lb).	
L	Total length of the direct damage profile for a given collision partner (in).	
N	Total number of equally spaced nodal points utilized for discretizing a continuum crush profile.	
b_o	Damage onset speed as per the Campbell model (ft/sec).	
c_i	The depth of crush at the ith discretized node (in).	
m	Vehicle mass (slugs).	
Δc_i	Change in value of crush at the ith discretized node (in).	

C

Case Study Solution

For years, crash analysis using a "momentum based solution"[1] has been based on an assumption that a car-to-car collision at "highway speeds" or "typical collision speeds encountered in traffic accident reconstruction cases…"[2] the crash could be treated as "inelastic."

More recently; however, particularly with the greater emergence of simulation programs (i.e.: HVE by Engineering Dynamics Corp) crash reconstructionists have come to recognize that crashes aren't really inelastic, even at "highway speeds." This case problem, with an impact/closing velocity of 49mph (80km/h), would seemingly fall into the category of one at a "highway speed" and the idea that the equally weighted target car would leave the collision faster than the bullet suggests some elasticity.

So, what are we talking about here? What explains the target car in the case problem leaving the crash faster than the bullet car if they're the same weights? If the collision were really inelastic and the cars acted like "two lumps of clay," their post impact velocities should be the same….but they weren't. In this crash test, we know:

Bullet speed at impact: 49.9mph (80.3km/h)   Target speed at impact: stopped
Bullet delta-V: -28.2mph (-45.4km/h)   Target delta-V: -28.2mph (-45.4km/h)
Bullet post impact speed: 21.7mph (34.9km/h)   Target post impact speed: 28.2mph (45.4km/h)

The "separation velocity" in this system is about 6.5mph (10.5km/h) meaning "something" caused the target to "bounce" away from the bullet such that, after impact, it's moving away from the bullet at about 6mph. If the collision were inelastic, that's couldn't happen.

So, you're sitting on the stand and you've calculated your post impact speeds and used those in a momentum analysis and find the impact sped of the bullet in this example. Now the line of questions by the opposing side's lawyer:

Q: You calculated, for post impact speeds, 21mph and 28mph for the bullet and target, respectively, right?
A: Yes.
Q: When you were taught to use conservation of linear momentum' to find the speeds of the cars at impact, were you told the crashes like this were inelastic and that highway speed collisions between vehicles are almost totally inelastic?'
A: Yes.
Q: Well, if that's the case, shouldn't their post impact speeds be the same?
A: _____

What are you going to say? You know the lawyer's going to have one of the books referenced here in his hands, page marked, ready to have you read the passage aloud to the jury. Then, once he's established that, he's going to ask:

Q: So, I want you to assume all the other values in your momentum analysis' are the same except I want you to adopt, for this hypothetical, that you believe what we see in these books, the crash is inelastic and the post impact speeds are the same for both cars. Assume that they're both moving at 28mph post impact because the collision is inelastic so they should be moving out together at the same speed. With that in mind, I want you to calculate the impact speed for the bullet vehicle.
A: Er, uh, 56mph
Q: You previously calculated 49mph, right?

Now, in the bigger picture, we're talking about a "6mph difference" but he's going to pitch that as more like a 12-13% "error" and, to a jury, if you were previously "solid" on your calculated 49mph speed, together with the passages from so many books, this starts to look like something is wrong with your analysis. At least, a shrewd lawyer might be able to paint it that way particularly if you're not prepared to explain what's going on.

Figure 6: Impact - Photo 1 of 2

Figure 7: Impact - Photo 2 of 2

Figure 8: Bullet car post crash

What IS going on? The answer, of course, is: restitution or the coefficient of restitution. The coefficient of restitution of a system is a fractional value representing the ratio of the velocities before and after an impact. In this case, we can calculate the coefficient of restitution (*e*) as:

$$e = \frac{V_s}{V_c}$$

Where V_s is 28.2mph -21.7mph= 6.5mph and V_c is 49.9mph which, in the case problem comes to a coefficient of restitution of 0.13. While not a "huge" number, quantitatively, it is clearly more than "0" or totally inelastic.

Restitution can also be described as the amount of "bounce between two objects" or the difference between static and dynamic crush. In the context of a barrier crash test, the rebound of the car off the barrier is a function of restitution. The photo of the Dodge Aries at 12.7mph (20.4km/h) into the barrier resulted in a rebound of about 1.1mph (1.8km/h). While that means the calculated restitution for that barrier crash was only about 0.7, it IS measurable and does explain the rebound. Without restitution, if collisions were inelastic, the car would have stuck to the barrier, would not have rebounded.

Another example of restitution is the "executive desk toy" called the "Newton's Cradle." We've all seen it, the series of balls suspended from a frame. Drop one ball on one end and the one on the other end bounces out from the line. Another example of restitution. The Collision Safety Institute did a crash test with three cars for the South Carolina Association of Reconstruction Specialists that, like the "Newton's Cradle," put one car (ball) into another and the one on the other side of that was bounced away, again leaving faster than the one behind it, the middle car.

And did you know that restitution is "regulated?" When golf club manufacturers began making thin-faced drivers with a so-called "trampoline effect," the US Golf Association started testing drivers for coefficient of restitution striking golf balls and has placed the upper limit for that, for drivers at 0.83. Benchmark conditions for the coefficient of restitution for Tennis racquets and tennis balls is 0.85 and the International Table Tennis Federation specifies that the ball and paddle must have a coefficient of restitution of 0.94.

Figure 9: Target car post crash

Figure 10: From the IATAI crash tests in Danville, Illinois in 2001, the car in
this 13 mph barrier crash test rebounded off the barrier. The rebound is a
function of restitution.

In the context of the difference between static damage and dynamic damage, for example, the FHWA/NHTSA National Crash Analysis Center (NCAC) is studying that difference in crash tests with a ShapeTape system by Measurand Inc of Fredericton, New Brunswick, Canada and some of their crew will be at the 08 ARC-CSI Crash Conference in Las Vegas and you can expect a review of their research in an upcoming issue of collision. Suffice it to say, however, that this groundbreaking research will help document intrusion which, among other things, can better explain injuries and potentially lead to improvements in car design.

So, does restitution matter? Well, New York Senator Daniel Patrick Moynihan once said "Everyone is entitled to his own opinion, but not his own facts."   **C**

Editor's note: Calls, letters or email with the phrase "this restitution thing, it only applies in civil cases, right?" will be ignored...

[1]"Momentum Applications in Traffic Accident Reconstruction," NUTI, Fricke, et al. Topic 868 p68-4

[2]Alternately called "conservation of linear momentum" or incorrectly described as "conservation of angular' momentum" for other than in-line collisions, for our purposes here, we'll simply refer to the application of a vector based model used to solve for impact speed(s) as a "momentum based solution."

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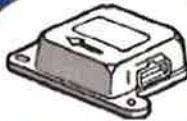
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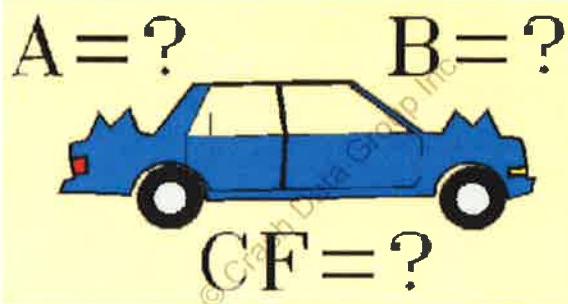
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